ERSATZ-11
PDP-11 EMULATOR
DEMO VERSION 7.1

FOR 30-DAY COMMERCIAL EVALUATION ONLY

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Contents

1 Introduction **1**

1.1 Emulated block device types . . . 2

1.2 Emulated sequential device types . . . 3

1.3 Emulated serial device types . . . 3

1.4 Emulated network device types . . . 3

1.5 Emulated DDCMP device types . . . 3

1.6 Miscellaneous device types . . . 4

1.7 PC hardware support . . . 4

1.8 Device names . . . 6

1.9 Filenames . . . 8

1.10 Notes . . . 9

1.10.1 Interrupts . . . 9

1.10.2 Host systems . . . 9

1.10.3 Copyright and licensing . . . 10

1.11 Acknowledgments . . . 10

1.12 History . . . 11

2 Installation and Configuration **13**

2.1 System requirements . . . 13

2.2 Installation . . . 14

2.3 Configuration . . . 15

3 Transferring the PDP-11 Operating System to the PC **18**

3.1 SCSI disks . . . 18

3.2 SCSI tapes . . . 19

3.3 Kermit . . . 19

3.4 Ethernet . . . 19

3.5 ASCII serial dump . . . 20

3.6 System-specific notes . . . 21

3.7 Utilities . . . 21

4 Disk Devices **23**

4.1 Disk cache . . . 24

4.2 Padding short volumes . . . 24

4.3 PC disk devices . . . 24

4.3.1 Disk image files . . . 25

4.3.2 Raw SCSI disk drives . . . 26

4.3.3 Raw BIOS disk drives and partitions . . . 28

4.3.4 Raw floppy disk drives . . . 29

4.3.5 Catweasel floppy disk drives . . . 31

4.3.6 Raw CD-ROM drives . . . 31

4.3.7 RAM disk drives . . . 31

4.3.8 Disks with intentionally bad blocks . . . 32

4.3.9 Null disk drives . . . 32

4.4 Emulated PDP-11 disk devices . . . 33

4.4.1 DB: — RP04, RP05, RP06 . . . 33

4.4.2 DC: — RC11/RS64 . . . 34

4.4.3 DD: — DL11/TU58 . . . 34

4.4.4 DF: — RF11/RS11, DDC DMS-11X/SSDM 100 (called RF: in RT-11) . . . 35

4.4.5 DK: — RK02, RK03, RK05 DECpack (called RK: in RT-11) . . . 36

4.4.6 DL: — RL01, RL02 . . . 36
4.4.7 DM: — RK06, RK07 . . . 37
4.4.8 DP: — RP02, RP03 . . . 37
4.4.9 DR: — RM02, RM03, RM05, RM80, RP07 . . . 38
4.4.10 DS: — RS03, RS04 . . . 39
4.4.11 DT: — TU55, TU56 DECtape . . . 39
4.4.12 DU: — MSCP disks . . . 39
4.4.13 DX: — RX01 . . . 40
4.4.14 DY: — RX02, "RX03" . . . 41
4.4.15 FX: — Fox 2/30 "drum" . . . 42
4.4.16 HD: — Hypothetical disk . . . 42
4.4.17 PD: — PDT-11/150 RX01 . . . 43
4.4.18 QX: — Terak 8510/a single-density disk . . . 43

5 Tape Devices **44**

5.1 Experimental tape cache . . . 44
5.2 PC tape devices . . . 45
5.2.1 Tape image files . . . 45
5.2.2 Raw SCSI tape drives . . . 46
5.2.3 RAM tape drives . . . 46
5.2.4 Null tape drives . . . 47
5.3 Emulated PDP-11 tape devices . . . 47
5.3.1 CT: — TU60 DECcassette . . . 47
5.3.2 MM: — TE16/TU16, TU45, TU77 . . . 48
5.3.3 MS: — TK25, TS04, TS05, TU80 . . . 49
5.3.4 MT: — TS03, TU10 . . . 50
5.3.5 MU: — TMSCP tapes . . . 50

6 Serial Lines **51**

6.1 PC serial devices . . . 52

6.1.1 Serial options common to all devices . . . 52

6.1.2 Video consoles . . . 54

6.1.3 COM ports . . . 55

6.1.4 PC line printer port . . . 56

6.1.5 Sealevel ports based on Zilog Z8530/Z85230 (E)SCC USART . . . 57

6.1.6 Sound Blaster MIDI port . . . 58

6.1.7 Telnet servers . . . 58

6.1.8 Single-port Telnet servers . . . 59

6.1.9 Telnet clients . . . 59

6.2 PC serial pseudo-devices . . . 60

6.2.1 Hayes-compatible dialup modems . . . 60

6.2.2 Kermit file-transfer protocol . . . 60

6.2.3 Throttled I/O . . . 60

6.2.4 Multiple physical ports on one emulated line . . . 61

6.3 Emulated PDP-11 serial devices . . . 62

6.3.1 LP: — LP11, LPV11 line printer ports . . . 62

6.3.2 TT: — DL11, DLV11 single serial line units . . . 62

6.3.3 XU: — DU11, DUV11 single serial line units . . . 62

6.3.4 YZ: — DZ11, DZQ11, DZV11 4/8-line serial multiplexers . . . 63

6.3.5 PT: — PDT-11/130 TU58 . . . 63

7 Network Devices **65**

7.1 PC network devices . . . 66

7.1.1 ETH*n*: — shorthand for other interface names . . . 66

7.1.2 NE2000: — NE2000 and compatibles . . . 66

7.1.3 PCNET: — AMD PCnet-PCI . . . 67

7.1.4 PKTD: — Packet drivers . . . 67
7.1.5 RTL8139: — RealTek RTL8139-based PCI Ethernet boards . . . 68
7.1.6 RTL8169: — RealTek RTL8169-based PCI Ethernet boards . . . 68
7.1.7 TULIP: — DEC/Intel Tulip-based PCI Ethernet boards . . . 68
7.1.8 VELOC: — VIA Velocity-based PCIe Ethernet boards . . . 68
7.1.9 Ethernet tunneling over UDP . . . 69
7.2 Emulated PDP-11 network devices . . . 70
7.2.1 NI: — Interlan NI1010A, NI2010A Ethernet ports . . . 70
7.2.2 XE: — DELUA Ethernet port . . . 70
7.2.3 XH: — DELQA Ethernet port . . . 71

8 DDCMP Network Links **72**

8.1 Emulated PDP-11 DDCMP network links . . . 72
8.1.1 XD: — DMP11, DMV11 multidrop link . . . 72
8.1.2 XM: — DMR11, DMC11 point-to-point link . . . 72
8.2 PC DDCMP drivers . . . 73
8.2.1 ASYNC: — Asynchronous serial ports . . . 73
8.2.2 NULL: — Null device . . . 73
8.2.3 SYNC: — EXPERIMENTAL synchronous serial ports . . . 73
8.2.4 TCP: — TCP network connection . . . 74
8.2.5 UDP: — UDP datagrams . . . 74

9 Miscellaneous Devices **76**

9.1 Installable user-written plug-in emulation modules . . . 76
9.2 ROM devices . . . 77
9.3 CD: — CD11 punched card reader . . . 78
9.4 CR: — CR11, CM11 punched card reader . . . 78
9.5 DO: — PC file access pseudo-device . . . 79

9.6 IX: — IEU11A, IEQ11A dual GPIB interface . . . 80
9.7 KD: — M8644 countdown register board . . . 80
9.8 KG: — KG11A communications arithmetic board . . . 81
9.9 KP: — KW11P programmable clock . . . 81
9.10 OA: — DR11C, DRV11 digital I/O ports . . . 82
9.10.1 ETHER: — Point-to-point IPL using Ethernet . . . 82
9.10.2 NULL: — Null device . . . 82
9.11 PP: — PC04 paper tape punch . . . 82
9.12 PR: — PC04 paper tape reader . . . 83
9.13 TK: — Terak bitmapped graphics display . . . 83
9.14 VR: — VT30 color graphics display processor . . . 84
9.15 VT: — VT11 vector graphics display processor . . . 84
9.16 XA: — DR11W, DR11B, DRV11WA, DRV11B digital I/O ports . . . 85
9.16.1 ETHER: — Point-to-point IPL using Ethernet . . . 86
9.16.2 NULL: — Null device . . . 86
9.17 XN: — DN11 auto-dialer controller . . . 86

10 Commands **88**

A Keyboard Script Language **110**

A.1 Default keyboard layout . . . 110
A.2 Keyboard script statement descriptions . . . 111
A.3 Key names . . . 116
A.4 Flags . . . 118
A.4.1 Read/write flags . . . 119
A.4.2 Read-only flags . . . 119

B Debugging Features **120**

B.1 Displaying and modifying memory . . . 121

B.2 Assembly and disassembly . . . 122
B.3 Registers . . . 122
B.4 Breakpoints and single-stepping . . . 122
B.5 Memory mapping . . . 123
B.6 Device logging . . . 123
B.7 Loading and dumping memory . . . 123
B.8 Switch and display registers . . . 124

C Installable Plug-ins **125**

C.1 Calling conventions . . . 125
C.2 Entry conditions . . . 126
C.3 Exit conditions . . . 126
C.4 Building plug-in modules . . . 126
C.5 Entry points . . . 127
C.5.1 Ersatz-11 environment . . . 127
C.5.2 I/O device emulation . . . 128
C.5.3 PDP-11 instruction emulation . . . 130
C.5.4 PC memory management . . . 133
C.5.5 Fork queue . . . 133
C.5.6 PC hardware access . . . 134

D TCP/IP Network Subsystem **136**

E Microcomputers **138**

E.1 PDT-11/130 . . . 138
E.2 PDT-11/150 . . . 138
E.3 Terak 8510/a . . . 139

F PDP-11/74 and PDP-11/45 Multiprocessing (EXPERIMENTAL/UNSUPPORTED) **140**

F.1 CPUs and console terminals . . . 141

F.2 Busses . . . 142
F.3 II: — DIP11A interprocessor interrupt and sanity timer . . . 142
F.4 Configuring RSX-11M-PLUS for multiprocessing . . . 143
F.5 Multiple PDP-11s with non-shared memory . . . 144
F.6 DPDISK: — Dual-ported disk . . . 145
F.7 DPTAPE: — Dual-ported tape . . . 145
F.8 FASTBUS: — Fastbus memory on detachable Unibus segment . . . 145
F.9 IPL: — Internal inter-processor link . . . 146

G Dates and Times **147**

G.1 Booting . . . 147
G.2 PC clock . . . 147
G.3 Year 2000 issues . . . 148
G.3.1 KDJ11E TOY clock . . . 148
G.3.2 Dates in RT-11 and TSX-Plus . . . 148
G.3.3 Dates in RSX . . . 149
G.3.4 Dates in RSTS/E . . . 149
G.3.5 Dates in Fuzzball . . . 149
G.3.6 Dates in Unix . . . 149

Chapter 1

Introduction

Ersatz-11 is a software replacement for PDP-11 minicomputer systems. When running on typical PC hardware, it substantially outperforms any PDP-11 model ever produced by DEC, outpaces all known aftermarket clone CPUs, and is the fastest PC-to-PDP-11 software emulator available at any price. Yet it is the most inexpensive PDP-11 replacement product on the market.

The achievable performance continues to increase as new IA32-compatible CPUs are released, so future upgrades are possible without requiring that a new PDP-11 CPU board be purchased. The emulated system is configured using simple commands, allowing the flexibility to duplicate almost any existing system easily. The configuration of the emulated system can be changed at any time, even while the system is running. Wherever possible, E11 provides useful defaults, to simplify the configuration process. It will choose between Q-bus and Unibus controller models depending on the emulated CPU type, and will auto-compute "floating" CSR and vector addresses, for devices that use them. It also chooses the default interrupt priority level according to the CPU type, since in many cases the Q-bus version of a peripheral interrupts on level 4 even though the original Unibus version uses level 5. In all cases these defaults can be overridden with `SET` commands.

Ersatz-11 emulates the entire PDP-11 system in software, including most standard disks, tapes, serial devices, and network interfaces. Facilities are provided to integrate non-standard device emulations into E11 when necessary. E11 is intended to boot and run any PDP-11 operating system. It has been tested with RT-11 (all flavors), RSX-11M, RSX-11M-PLUS, RSTS/E, IAS, TSX-Plus, 2.9BSD and 2.11BSD UNIX, DSM-11, DOS/BATCH, Fuzzball (BOS), the Fox 2/30 OS, and XXDP+.

Emulated configuration

- PDP-11/03, PDP-11/04, PDP-11/05, PDP-11/20, PDP-11/23, PDP-11/24, PDP-11/34a, PDP-11/40, PDP-11/44, PDP-11/45, PDP-11/53, PDP-11/60, PDP-11/70, PDP-11/73, PDP-11/74, PDP-11/83, PDP-11/84, PDP-11/93, or PDP-11/94 CPU with individually selectable features
- FP11/FPF11/FPJ11 (etc.) floating point processor, FIS floating instruction set option, KE11A/B extended arithmetic element (EAE)
- 4 MB main memory
- Many different models of disks, tapes, serial and network devices (see tables below).

1.1 Emulated block device types

dev name	*controller type(s)*	*drive type(s)*
DB:	RH11, RH70	RP04/05/06 pack drive
DC:	RC11	RS64 fixed-head disk
DD:	DL11	TU58 cartridge tape
DF:/RF:	RF11, DMS-11X	RS11 fixed-head disks, DDC SSDM 100 RAM disk
DK:/RK:	RK11D	RK02, RK05 front-loading cartridge drive
DL:	RL11[1], RLV11, RLV12	RL01, RL02 top-loading cartridge drive
DM:	RK611[2]	RK06, RK07 top-loading cartridge drive
DO:	(virtual)	Ersatz-11 interface to host file system (for DO.SYS/DOS.TSK/LNX.TSK)
DP:	RP11C	RP02, RP03 pack drive
DR:	RH11, RH70	RM02/03/05 pack drive, RM80/RP07 Winchester
DS:	RH11, RH70	RS03/RS04 fixed-head disk
DT:	TC11	TU55/TU56 DECtape
DU:	UDA50, KDA50 RQDX3, RQZX1	RA60, RA70–73, RA80–82, RA90/92, RC25, RD31–32, RD50–54, RX33/RX50 MSCP disk
DX:	RX11, RXV11	RX01 8” SS SD floppy
DY:	RX211, RXV21	RX02 8” SS DD (or DS DD) floppy
FX:	Fox 2/30 DBI	DDC 6200 “drum” (actually a fixed-head disk)
HD:	(virtual)	Ersatz-11 hypothetical disk with simplified interface (for HD.SYS)
PD:	RXT11	RX01 8” SS SD floppy (PDT-11/150 microcomputer)

[1] “RL211” was used as a marketing name in systems with RL02 drives, but is the identical controller to the RL11.
[2] “RK711” was used as a marketing name in systems with RK07 drives, but is the identical controller to the RK611.

1.2 Emulated sequential device types

dev name	*controller type(s)*	*drive type(s)*
CT:	TA11	TU60 DECassette dual cassette tape
MM:	RH11/RH70 + TM03	TE16, TU45, TU77 Massbus magtape drive
MS:	TS11, TSU05/TSV05, M7454, TQK25	TS04, TS05, TU80 magtape drive, TK25 cartridge tape drive
MT:	TM11	TS03, TU10 magtape drive
MU:	KLESI, TQK50, TQK70	TU81, TK50, TK70 TMSCP tape
PR:/PP:	PC11	PC04 high speed paper tape reader/punch

1.3 Emulated serial device types

dev name	*port type(s)*	*description*
TT:	DL11, DLV11	single serial line unit
LP:	LP11, LPV11	line printer interface
XU:	DU11, DUV11	async/sync serial line unit
YZ:	DZ11, DZQ11, DZV11	serial PIO multiplexer
PT:	PDT-11/130	serial line for TU58

1.4 Emulated network device types

dev name	*port type(s)*	*description*
NI:	NI1010A, NI2010A	Interlan Unibus/Q-bus Ethernet interface
XE:	DELUA, DEUNA	Unibus Ethernet interface
XH:	DELQA, DEQNA	Q-bus Ethernet interface

1.5 Emulated DDCMP device types

dev name	*port type(s)*	*description*
XD:	DMP11, DMV11	multidrop network link
XM:	DMR11, DMC11	point-to-point network link

1.6 Miscellaneous device types

dev name	*port type(s)*	*description*
`CD:`	CD11	punched card reader
`CR:`	CR11, CM11	punched card reader
`DO:`	(virtual)	PC file interface
`IX:`	IEU11A, IEQ11A	dual GPIB ports
`KD:`	M8644 CDR	countdown registers
`KG:`	KG11A	communications arithmetic board
`KP:`	KW11P	programmable clock
`OA:`	DR11C, DRV11	programmed digital I/O board
`TK:`	Terak	bitmapped graphics display
`VR:`	VT30	color graphics display
`VT:`	VT11	vector graphics processor
`XA:`	DR11W, DR11B, DRV11WA, DRV11B	DMA digital I/O board
`XN:`	DN11	auto-dialer controller

1.7 PC hardware support

- Block devices: disk image files, raw SCSI disk drives, raw floppy drives, raw CD-ROM drives, RAM disks, Catweasel floppy drives
- Tape devices: tape image files, raw SCSI tape drives, RAM tapes
- Character devices: Emulated VT100 on SVGA (can flip between up to 12 virtual screens), COM, LPT, Sound Blaster MIDI ports
- Network devices: NE2000 clones, RealTek RTL8139, RealTek RTL8169, AMD PCnet-PCI, DEC Tulip, VIA Velocity, packet drivers

This is a stripped-down demonstration version of Ersatz-11, which when used for commercial purposes may only be installed for an evaluation period limited to 30 days. After this time, commercial users must either buy E11 (either the "Lite" or full version), or delete all copies of the demo version in their possession. *There is no limitation on hobby/personal use of this demo package.* Commercial use is defined as anything having to do with the operation of a for-profit business. Older versions of Ersatz-11 (V1.1A and earlier) had no such limitation on use, so this notice does not apply to them, however they are no longer supported by D Bit.

This demo version of Ersatz-11 is available from `www.dbit.com`.

The emulator speed depends on the application and the host system. In general E11 on any speed Pentium III, Pentium IV, or Athlon runs on the order of ten to twenty times the speed of a PDP-11/93. E11's disk I/O is much faster than that of real PDP-11s, especially when run under an operating system which provides good disk caching.

The FP11 floating point processor emulation currently requires a math coprocessor (which is built into all current 80x86 CPUs anyway). If the PC has none, then the emulated PDP-11 will have no FPP either. Intel Pentium CPUs that have the floating point divider bug are detected and a workaround is used to get correct results at a slight speed penalty (for `DIVF`/`DIVD` only). The FIS emulation does not require a math coprocessor.

The system has been tested under the XXDP+ diagnostic monitor. It passes the KD11EA diagnostics DFKAA, DFKAB, and DFKAC, and the FP11A diagnostics DFFPA, DFFPB, and DFFPC. It does not work with MMU diagnostics due to the absence of the maintenance mode. It has been found that passing or failing DEC diagnostics does not bear much relation to actual operation with real-world software and operating systems, because the diagnostics are designed mainly to detect known failure modes of real DEC hardware, and not to verify new implementations.

1.8 Device names

With the exception of PC files, just about every I/O device used by Ersatz-11 has a device name ending in a colon (“:”). This applies to both emulated PDP-11 devices and real PC hardware devices. Each device (disk unit, serial line, etc.) has a name that normally conforms to the following prototype:

dev[*c*][*u*]:

dev Alphabetic device name identifying the device type: always two letters for emulated PDP-11 devices, variable for PC hardware devices.

c Optional letter (A–Z) identifying which of the (potentially) multiple controllers of the same type is controlling this particular device. Specified only with controllers that can support multiple devices. A reasonable default is used if it is omitted, generally the first or only controller of that type. The controller letter is always displayed in output from the SHOW command for devices where it is meaningful, so the name given by SHOW will have the letter even if you didn't specify one. In the demo version of E11, the RH11/RH70 Massbus controllers, TC11 DECtape controllers, and `HD:` pseudo disks are the only controller types of which there may be more than one. All other types will always use controller `A` so the default is always the only choice.

u Optional unit number identifying the device; default is the first unit on the controller. The unit number should be omitted when referring to the controller as a whole (e.g. SET commands).

The two-letter device names for emulated PDP-11 devices are taken from the names used by the popular PDP-11 operating systems. Where possible, synonyms are available to ensure that the device names will be familiar to users of each operating system. For example, DELUA ports may be referred to using either the RSTS/RSX name (“`XE:`”), or the RT-11 name (“`NU:`”), and similarly, RK05 disk units may be called “`DK:`” or “`RK:`”.

However E11 uses a more consistent naming system than these operating systems do, since the first two letters of a PDP-11 device name *always* depend on the controller type.

In some cases this leads to differences, for example “`TT`*u*`:`” (or “`KB`*u*`:`”, which is a synonym) refers specifically to a DL11/DLV11 serial port, while in RSX and RSTS, *all* terminal ports are mapped to one of these names regardless of the port type. But in E11, a serial port located on a DZ11/DZV11 is always “`YZ`*cu*`:`”. As a result, the device names used by E11's command language may not necessarily be identical to those used by the operating system for the same devices.

The device names for PC hardware are the same as those used by DOS for those devices that actually have names in DOS. So `CON:` refers to the first video session, `COM1:`–`COM4:` are serial ports (`AUX:` is a synonym for `COM1:`), `LPT1:`–`LPT4:` are parallel ports and (`PRN:` is a synonym for `LPT1:`). For other devices a short mnemonic name is used, with an optional letter identifying the controller for devices like multi-port serial interfaces where a port number alone isn't enough to uniquely identify the device. Note that PDP-11 unit numbers always start at 0 (TT0:, DU0:, MU0: etc.) while PC unit numbers generally start at 1 (COM1, LPT1).

For a very few devices (both real and emulated), identifying the controller and unit isn't enough since there may be multiple slaves attached to the same master unit. In this case the device name is expanded to look like “*dev*[*c*][*u*][_*s*]:”, where *s* is the optional slave number within unit *u*. This form is rarely used since it only makes sense on emulated Massbus tape drives with multiple slaves attached to the same formatter, or on SCSI devices with multiple LUNs within the same target such as the old Adaptec ACB-4000A SCSI/MFM bridge boards. In any case if *s* is omitted (as well as the preceding underscore) a reasonable default is used.

The `ASSIGN`, `DEASSIGN`, `MOUNT`, `DISMOUNT`, and `SHOW` commands can usually accept a PDP-11 device name with a range of unit numbers, such as “`DU0-3:`”. With this syntax, every unit in the range is created, deleted, or displayed

with just one command. For `ASSIGN` and `MOUNT`, the PC device name (or filename) is automatically modified for the second and later units using sensible rules which will usually give a useful result. This can be handy for things like populating a serial multiplexer.

1.9 Filenames

A few rules apply to PC files referenced using E11 commands. When a reference is made to an existing file, without a drive name or directory path in the file specification, E11 searches for it first in the current directory, then in the directory where the E11 executable file is located (under DOS V3.0 and later), then in the directories listed in the `PATH` environment variable. A filename may be enclosed in single (') or double (") quotes to allow lower case or special characters in the name, however this is useful only when running on a system that supports the "long filenames" extended DOS calls. Path elements must be separated by "\" characters, except when the file specification is enclosed in single or double quotation marks in which case either forward slashes or backslashes may be used. Each command that takes a filename has a default extension which is added when none is supplied by the user.

Typical default extensions are:

.ext	*type of file*	*relevant command*
`.CMD`	command file	@[*d*:*path*\]*filename*
`.CRD`	punched card binary image	ASSIGN CD:/CR:
`.DSK`	disk image file	MOUNT
`.INI`	init file	/INITFILE switch
`.LOG`	log file	LOG
`.PAP`	paper tape image file	MOUNT PR:/PP:
`.PDP`	binary memory image	LOAD, DUMP
`.TAP`	tape image file	MOUNT
`.TIM`	opcode timing file	SET THROTTLE
`.TXT`	punched card text file	ASSIGN CD:/CR:

1.10 Notes

1.10.1 Interrupts

The emulated interrupt system is somewhat complicated, mainly due to some assumptions in DEC OSes (particularly RSX and RT-11 SJ) about how many instructions are guaranteed to be executed after writing a command to a device CSR, before the device will complete the operation and interrupt. On the PC, some I/O may complete much faster than on a real PDP-11, and it even appears to be instantaneous with RAMdisks/RAMtapes (and disk/tape image files under MS-DOS), since the I/O is performed synchronously between PDP-11 instructions. Unfortunately this causes trouble with some drivers that depend on being guaranteed the time to execute a certain number of instructions before the completion interrupt occurs.

This is not actually a bug if it works on all real PDP-11 models, but it leads to incorrect operation if the emulated hardware appears to be fast enough to complete an operation before the expected minimum number of instructions is executed. Under testing, RSX appeared to issue `WAIT` instructions for TTY output which was assumed not to have completed yet a few dozen instructions after writing a character to a DL11 (thus hanging the system), and similarly the RT-11 SJ (but not FB/XM) keyboard interrupt service routine runs with interrupts enabled on the assumption that another keyboard interrupt couldn't possibly happen before the current ISR finishes. When this does happen the ISR recurses and the characters are put in the buffer in reverse order, which was happening with VT100 keypad keys in early versions of E11.

The solution to these problems is to use a queueing system, so that the interrupt (and in many cases the transfer itself) doesn't occur until a pre-set number of instruction fetches after the instruction that started the transfer. The default delays are intended to be adequate for most users. However when troubleshooting with custom operating systems, this is a good place to experiment if E11 appears to work with your application using certain emulated devices, but not others. Much less trouble has been experienced with disks and tapes, so by default most of them are set to execute all functions in one instruction time. The RSX MSCP initialization sequence is an exception, so the default delays are tuned appropriately. The RK11 handler in DOS/BATCH requires an unusually slow disk controller, so in order to use that you must first issue a command like `SET DELAY RK11D *=8000` to make all RK11D disk commands take 8000 instruction fetches to complete. For reasons given above, the character-at-a-time devices have larger default delay counts. RK05/06/07 seek completion attentions may be delayed still further beyond acknowledging the seek command, so as not to confuse overlapped seek drivers. However you'll get faster results using a non-overlapped driver if one is supplied with your OS. Since all your emulated disks will typically be on one physical PC disk with only one head carriage, there's nothing to overlap anyway.

1.10.2 Host systems

D Bit occasionally receives inquiries from users who want Ersatz-11 to be ported to architectures other than the 80x86. There are no plans to port E11 to other processors. Besides the expense and difficulty of moving software between radically different host systems, D Bit is considers its ability to provide adequate customer support to be of primary importance, and this would not be possible if there were too many different versions of E11.

Rather than produce poorly supported versions of E11 for a myriad of host systems which provide more hindrance than help to the task of emulating a PDP-11 system, D Bit has chosen to focus its efforts on the 80x86 architecture under Linux, OS/2, Win32, and DOS. This hardware has the best price:performance ratio of anything currently available, it's what the vast majority of E11 customers are already running anyway, and its programming architecture lends itself well to efficient PDP-11 emulation. The supported operating systems are inexpensive and easy to install (some more than others), and they provide a good set of helpful services to E11 but also allow easy access to hardware so that Ersatz-11 has the control it needs, adequate DOS emulation is available in a variety of other operating systems, so that again, most users already have a system which is capable of running E11.

1.10.3 Copyright and licensing

Ersatz-11 is Copyright © 1993–2014 by Digby's Bitpile, Inc. All rights reserved. Distribution of this document and/or the `INSTALL.EXE` auto-installing executable file (demo version only) in unmodified form, without charge, is allowed pursuant to the usage restrictions given at the beginning of this document. Anything else is strictly forbidden.

1.11 Acknowledgments

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1.12 History

31-Oct-1993; development started.

V0.8 BETA, 29-Mar-1994; initial release.

V0.9 BETA, 05-Jul-1994; many bug fixes (mainly trap handling, MMU emulation, `DIV` instruction, and VT100 reverse video), added RX211 emulation, multiple DL11s, and 50 Hz KW11L mode.

V1.0 BETA, 14-Nov-1994; more bug fixes, added FP11A, RK611/RK06–07, LP11, D-space, and supervisor mode emulation. Also `CALCULATE`, `HELP`, `INITIALIZE`, `LOG`, `SET/SHOW CPU`, `SET DR LPT`n`:`, `SET SCROLL`, `SHOW MMU` commands, VT100 graphics/underline, changed to `.EXE` file (ran out of space in unified code/data segment in .COM file).

V1.1 BETA, 22-Mar-1995; still more bug fixes (IAS finally works), DELUA Ethernet emulation, disk `LOG`ging, indirect command files, workaround for Pentium `FDIV` bug, help text moved to file, Russian `HD:` device (and RT-11 driver), PC11, display general registers on parallel port LED board.

V2.0 DEMO, 20-Jul-1997; many bug fixes as usual, limited 22-bit MMU with and without Unibus map. MMU SR1 mechanized, TOY clock, CPU emulation extended to include 11/24, 11/44, 11/45, 11/70, 11/94. Added RXT11/RX01, RK02/RK05, RS03/RS04, TU56, TU10, TU60, TE16/TU45/TU77 device emulation. Definable keyboard. Loadable ROM/EEPROM. Many new floppy types, which may now be used with any disk controller type.

(Many intermediate V2.0x full versions were released throughout 1997 and 1998.)

V2.1 Full version, 01-Apr-1999; runs in protected mode with full 22-bit MMU. MSCP, TMSCP, RMxx/RPxx, TS11, DZ11/DZV11, DHU11/DHV11, DEQNA device emulation. Support for Q/Unibus bridges. Boca, Chase PCI-FAST, Digi, RocketPort/PCI, SBMIDI serial drivers. NE2000 Ethernet driver. Physical port drivers for SCSI disk/tape drives, RAM disks/tapes. FLOATING address calculation, DEFAULT controller types. PDP-11/23, 53, 73, 83, 84, 93 CPU types added. Demo/Lite versions have a subset of these features.

V2.1A, 01-Oct-1999; concatenated image files to form one large disk, CDROMx: driver, other minor improvements and bug fixes.

V2.2, 01-Apr-2000; DH11, DM11BB, DR11C, VT11, Interlan NI1010A/NI2010A emulation, FIS instruction set, KE11A/B EAE, mini-assembler. Hardware drivers added or extended for DCI-1300 digital I/O boards, SVGA graphics, ISA RocketPorts, BCI-2004/BCI-2104 bus adapters, multiple physical serial devices. SCSI disk partitioning added. Most disk "write headers" commands perform low-level format. Documentation overhauled.

V3.0, 01-Oct-2000; Linux version released. DMS-11X RAM disk, SET THROTTLE, Data Products printer support, PCI LPT cards, configurable interrupt priorities. Additional SET CPU options to support early CPU models.

V3.1, 01-Jul-2002; Telnet server, TU58 cartridge tapes. Demo version for Linux, expanded limits on Demo/Lite versions.

V4.0, 01-Apr-2004; flat 32-bit version. DJ11, M8644 countdown register emulation, command line editing/recall. DOS version adds drivers for RocketPort "Universal" PCI boards, RealTek RTL8139 Ethernet ports, and autosizing in CDROM: (so DVDs work too). Win32-style "PE" .EXE format DLLs supported.

V4.0A, 01-Jun-2004; bug fixes for new flat version. Experimental Catweasel floppy driver. Win32-style DLL support improved and documented.

V4.0B, 15-Oct-2004; bug fixes. SET MEMORY, SET CPU USERMODE, SET CPU 03.

V4.1, 01-Sep-2005; bug fixes. SET CPU PRIO. DR11W, KW11P, and VT30 emulation. Drivers for LPT port as digital I/O device, and PCI 11W DMA board. THROTTLE: pseudo-driver. SET TELNET: BANNER=*file*. Support for extended CON: screen sizes, SHOW VIDEO. Timer code rewritten for greater precision, with Linux version using /dev/rtc if available.

V5.0, 01-Feb-2006; Win32 native version. CPU speedups. SET CPU 74, SET CPU 60, SET CPUS=*n*. SET TELNET: TERMINAL=*type*. LOG /NOTIMESTAMPS. ASSIGN ... /CD:*x* /CTS:*x* /DSR:*x* /RI:*x* /SRD:*x* (and SET equivalents). Up to 8 LP11s in full version. Many bug fixes.

V5.1, 01-Aug-2007; disk and tape caching. Raw BIOS hard disks and partitions. Driver for DCI-4100 digital I/O boards, many improvements to digital I/O board emulations and drivers. Bit 3 Q-bus adapters. Newer Q-/Unibus adapters from The Logical Company. SHOW PCI.

V5.2, 01-Aug-2008; mouse copy/paste. SET/SHOW PCLOG. SET CPU NOMMU speedups. ADDPCI. SCAN. Delays after bus adapter cycles. Emulated DMA to I/O page. New mP features for PDP-11/45s: FASTBUS:, IPL:, SET CPU NOSHAREDMEM.

V5.3, 01-Sep-2009; ATTACH BCI: and ASSIGN ... TELNET: in Win32 version. 64-bit memory addressing in DOS version. DIR, CD, TYPE commands. FAT file system driver in stand-alone version. Ethernet tunneling over UDP in Linux and Win32 versions.

V6.0, 01-Nov-2010; OS/2 native version. TCP/IP stack and drivers for NICs based on PCnet-PCI, Tulip, RTL8139, and Velocity chips in DOS and stand-alone versions. Ethernet booting. DELQA emulation (was DEQNA). TELSINGLE: and TELCLIENT:. LOG /NOBUFFERING and LOG /LAST:*n*. OpenGL graphics driver and new installer for Windows (and OS/2).

V6.1, 01-Dec-2012; EDIT. /MAC on all network devices (was just UDP:). PT: and SET CPU PDT11 for PDT-11/130,150 emulation. TK: and QX: for Terak 8510/a emulation. SET THROTTLE FILE=file. LASTSIMILARYEARBEFORE yyyy.

V7.0, 31-Oct-2013; E11's 20th birthday. CD11, CR11, DMR11/DMC11, DN11, DU11, IEU11 (framework only), and KG11 emulations. HAYES:, OSPRINT:, and SCC: drivers. Unit number ranges. VT100 smooth scroll, SETUP mode, and scrollback buffer. VT101 and VT102 emulation. NULL: devices for most device types. ASYNC*n*:, DIG*n*:, GPIB*n*:, PRINT*n*:, and SYNC*n*: host-OS-independent nicknames. Increased use of helper threads. LOG /PC. Disk logging calculates starting block numbers. LoadModule, GetSymbol, UnloadModule plug-in calls.

V7.1, 01-Jun-2014; DMP11/DMV11 emulation. TCP/UDP transport for DDCMP devices. Kermit clients. BAD:, DPDISK:, and DPTAPE: drivers. /NOPAD, /PAD:NULL, and /PAD:RAM. SET PCLOG *n*.

Chapter 2

Installation and Configuration

2.1 System requirements

Installation of Ersatz-11 requires the following:

- Intel 80x86-compatible PC with 80386 or later CPU
- At least 6 MB of available system memory (any additional memory may be used for RAM disks/tapes and disk/tape caches).
- 2 MB of available disk space for Ersatz-11 itself, plus space for all disk image files (equivalent to the size of the disk drives they replace).
- Microsoft MS-DOS, IBM PC-DOS, DRDOS Inc. DR-DOS, FreeDOS if properly patched (see ftp.dbit.com), or a DOS session in Windows, OS/2, or Linux.

Running Ersatz-11 under plain DOS gives better response time to external events, and better access to non-standard PC hardware. However, running in a DOS session under another operating system typically gives a dramatic increase in disk speed due to the improved disk caching. So the decision of which host operating system to use should be based on the exact needs of the PDP-11 system.

Issues to consider when selecting the host operating system:

- DOS itself has essentially no disk caching, and the add-on disk caches that are available typically do not work well with large disks and don't take advantage of the large amounts of RAM found on modern PCs. However, E11's internal disk cache works well, and DOS allows E11 unlimited access to special hardware (such as bus adapters), and it's generally very stable, inexpensive, and easy to install. And it's small enough that in some cases, an entire E11 system can boot and run from a single floppy disk.
- Windows 95 (or 98 or Me) has good disk caching, and doesn't interfere much with hardware access, but it has a very poor task scheduler. It significantly reduces the amount of CPU time that E11 gets when it is not the foreground (or full-screen) window, and often fails to deliver clock interrupts to E11, so the PDP-11's clock can appear to stop. Even if E11 is in the foreground window, Windows will occasionally suspend E11's execution for several seconds to perform housekeeping functions, which degrades response time and causes the PDP-11 clock to lose time.

- Windows NT/2K/XP/Vista/7 has good disk caching and a true pre-emptive scheduler, but it has very bad DOS emulation, and 64-bit versions have none at all. All accesses to hardware are intercepted and virtualized by the operating system, not accesses just to devices that are being shared with other programs. As a result, there's no way to access Ethernet ports or raw SCSI disk/tape drives or bus adapters, or anything else besides the basic core PC peripherals (screen, keyboard, display, COM/LPT ports etc.). Also, Windows isn't very reliable about delivering clock interrupts to E11, so the PDP-11 clock loses time.
- OS/2 has excellent disk caching (for native partition types), a true pre-emptive scheduler, good DOS emulation, and allows E11's built-in device drivers free access to hardware. The disadvantages of OS/2 are that it can be difficult to obtain (although eComStation is readily available), not well supported by IBM, and has poor caching of FAT partitions.

2.2 Installation

Installation is very straightforward. Simply download the installation program, and type:

```
C:\>install
```

The installation program will prompt for a directory into which to install, and will then extract all the E11 files from the distribution archive. The files are as follows:

file	*contents*
`E11.EXE`	executable
`E11.HLP`	"HELP" data file
`E11DEMO.PDF`	this document, readable with Adobe Acrobat
`HD*.*`	source and binaries for RT-11 HD: driver
`DO*.*`	source and binaries for RT-11 DO: driver
`KED.CMD`	keyscripts for using cursor keys with KED/EDT
`XHBOOT.BIN`	D Bit implementation of DELQA boot/diag ROM
`PDT130.PDP`	D Bit implementation of PDT-11/130 driver ROM
`PDT150.PDP`	D Bit implementation of PDT-11/150 driver ROM

E11's home directory is also a sensible place to put disk image files (*.DSK) and the E11.INI initialization file (see below), since E11 will look there if these files aren't found in the current working directory.

E11 conforms to the DPMI (DOS Protected Mode Interface) standard, which allows it to cooperate with protected mode operating systems and drivers. Windows, OS/2, and Linux dosemu always have a DPMI server in place when running a DOS session. Under plain DOS there may or may not be a DPMI server present (examples are Qualitas MAX, Quarterdeck QEMM, the version of EMM386 that comes with DR-DOS, the freely distributable CWSDPMI program which is available from the D Bit FTP server, and the non-commercial-use-only DPMIONE from Sudley Place). Ersatz-11 has a built-in protected mode supervisor which allows it to run on a plain DOS system if no DPMI compliant memory manager is present, however in this case E11 must be the only protected mode program executing on the system. So if there is no DPMI host, then HIMEM.SYS and EMM386.EXE should be disabled in CONFIG.SYS to avoid conflicts with E11's supervisor.

Drivers for most of the PC hardware that E11 controls are built into E11 itself, so there is often no need to load any external drivers or TSR programs. However there are some exceptions. These are listed below, along with the device emulations or drivers that may require them, and examples of typical lines that would be added to the CONFIG.SYS and/or AUTOEXEC.BAT files to load the drivers. The drivers themselves are supplied by the hardware vendor and/or the operating system.

driver	*needed by*	*typical command line*
Packet Driver	DELQA/ DELUA	PCIPKT 0x60 (in AUTOEXEC.BAT)
Mouse	CON:/ VT11	DEVICE=C:\MOUSE\MOUSE.SYS (in CONFIG.SYS) *or* C:\MOUSE\MOUSE (in AUTOEXEC.BAT)
CD-ROM	CDROM:	DEVICE=C:\SBCD\SBIDE.SYS /D:MSCD001 /V (in CONFIG.SYS) *and* C:\DOS\MSCDEX /D:MSCD001 (in AUTOEXEC.BAT)
ASPI manager	SCSI:	DEVICE=C:\SCSI\ASPI8DOS.SYS (in CONFIG.SYS)

Whether or not the above drivers will be needed depends on the configuration of the emulated system. Most common configurations don't require any of them. If needed, these drivers are installed by adding lines similar to the above examples to the CONFIG.SYS and/or AUTOEXEC.BAT files, using a text editor.

2.3 Configuration

Ersatz-11 is configured using a text file named "`E11.INI`," which is normally kept in E11's home directory. This file may be created using any text editor. It contains a series of commands which are read and processed in order every time E11 starts up. Lines which start with a "`;`" or "`!`" character are treated as comments, and ignored. Each individual serial line or emulated disk or tape unit is created with a one-line command. Typically there will also be additional commands to define the emulated CPU model, set any non-standard device addresses or device types, and finally the initialization file usually ends with a BOOT command which boots the emulated PDP-11's operating system. The table below summarizes which command is used to add each device type to the system. The syntax of each specific command is described in chapter 10.

device type	*command to create*
CPU	SET CPU
disk drive	MOUNT
tape transport	MOUNT
TTY line	ASSIGN
line printer	ASSIGN
network port	ASSIGN

Below is a typical `E11.INI` file. This file is read by Ersatz-11 every time it starts up, and the commands are executed in sequence, as if they were typed at the keyboard.

```
;
; Set PDP-11/44 CPU model
;
set cpu 44
;
; Mount disk and tape units
;
mount du0: rsx11m.dsk
```

```
mount du1: ra81.dsk
mount mm0: dump.tap
;
; Add extra DL11 terminal lines and LP11 printer port
;
assign tt1: con2:
assign tt2: con3:
assign lp0:   lpt1:
;
; Define 8-line DZ11 serial mux using Comtrol RocketPort/PCI
; (Rocket and DZ ports match 1:1 in this example, but it's OK to mix
; and match on a per-line basis)
;
; (Lite and Demo versions don't support Rocketports, so use CON:)
;
assign yza0--7: con4:
;
; Define DELUA Ethernet port using RealTek RTL8139-based Ethernet board
;
assign xe0: rtl8139a:
;
; Boot MSCP disk unit 0 (and switch keyboard to PDP-11 console)
;
boot du0:
;
; Control returns to the next line when the user presses Shift-Enter
; or the system halts on its own (e.g. SHUTUP.TSK)
;
quit
```

The "boot" command starts the PDP-11 operating system and directs keyboard input to the PDP-11 system console. The user can press Shift-Enter at any time to pop up an E11 command prompt where additional commands may be entered interactively. If there are unread lines remaining in "E11.INI" (i.e. following the "boot" command), they will be read at that time. In this example, the program will exit immediately when Shift-Enter is pressed because it causes the "quit" command to be read.

There are a few more basic options which are entered as switches on the E11 startup command line, rather than being contained in the "E11.INI" initialization file:

`/CONSIZE:`*W*x*H* Set the default size for all CON: screens, including the one implicitly ASSIGNed to TT0: at startup. The default is whatever the screen size was when E11 was started.

`/HELP` *(syn.* `/?`*)* Display a simple list of switches and their meanings, and exit without starting E11.

`/INITFILE:`*file*[`.INI`] Read the specified initialization command file instead of E11.INI.

`/IOPAGE:`*nnnn* Enlarge the I/O page past the usual 8 KB size, with *nnnn* specifying the decimal number of kilobytes. This is mainly useful with customer-written loadable device emulation modules which act like RAM windows, and is equivalent to the "Unibus fence" feature of some PDP-11s that have 22-bit memory addressing.

`/MEMORY:`*nnnn* Set the maximum possible emulated memory size of the PDP-11 to *nnnn* (decimal) kilobytes. By default this maximum is 4088 KB. If this amount is not available, E11 settles for whatever it can get (rounded down to a multiple of 8 KB) as long as it's at

least 8 KB. This switch allows you to conserve memory when emulating a PDP-11 with less memory than E11's default.

`/NOINITFILE` Do not process the E11.INI initialization command file.

When configuring the system for the first time, it is best to exactly duplicate the system which is being replaced. There may be a strong temptation to expand the system, now that PDP-11 peripherals are effectively "free" for the asking. But such changes can cause conflicts with existing software, which may contain hard-coded device names or other hidden assumptions about the system configuration. These problems may be avoidable, if system expansion is postponed until after the existing system is brought up as-is.

Note that some operating systems do little or no autosizing and may have problems if the hardware being emulated by E11 differs from the one for which the operating system was generated. In particular you may run into trouble if your OS depends on any static memory allocation (if E11 is emulating a different amount of memory than what the system expects), or if it is built for Q22 I/O and E11 is emulating a PDP-11/44 with Unibus map registers, or anything like that. Also, the routine in RSX-11M-PLUS that counts the number of registers in an RH70 depends on PDP-11/70 autoincrement semantics, and will get the wrong answer if you set the CPU type to PDP-11/44. This normally causes no problems, since real PDP-11/44s can't have RH70s, but this and other "impossible" situations can be easily created in E11.

One thing to watch out for, is that some software has hard-coded assumptions about how fast the hardware operates in relation to the CPU. See section 1.10.1 for a discussion of interrupt timing. This can lead to strange behavior, such as devices that simply hang, or supposedly I/O bound tasks that consume 100% of the CPU. These problems can generally be solved by experimenting on the relevant emulated devices with the `SET DELAY` command. If the system doesn't operate correctly with the default delay counts, but springs to life when they're increased to large numbers, then it's just a simple matter of tuning the numbers to get delays which are long enough that the system works reliably, but still give good performance. Ideally the PDP-11 device drivers should be updated so that they will operate correctly with "infinitely" fast hardware, since this will allow it to get the best possible performance out of *any* fast PDP-11 replacement, but the `SET DELAY` command allows the user to work around these problems without having to touch the PDP-11 software.

Chapter 3

Transferring the PDP-11 Operating System to the PC

In order to run an exact copy of a real PDP-11 system, the contents of the PDP-11's disk(s) must be accessible to Ersatz-11 to be used as emulated disks. In most cases, this means importing a byte-by-byte copy of each entire disk into a large "image" file which is the same size as the entire PDP-11 disk. Note that this is very different from importing the individual *files* from the PDP-11 disk. In some cases the files can be reassembled into a disk image, but if possible it's better to download the disk(s) as a single large image. The fewer transformations the data go through, the fewer opportunities for mistakes that could lead to file damage.

Getting a snapshot of a bootable disk from an existing PDP-11 into a PC file can be tricky, there are many ways to do it and which choice is the best one depends on what software and hardware are available, and what media or protocols the PDP-11 and PC have in common. D Bit can help with some forms of media translation, call or send email for information. DEC, Mentec, and S&H are all now willing to sell PDP-11 OS licenses to emulator users, there doesn't seem to be an issue about the lack of a CPU serial number. So ordering the latest OS version is straightforward, and with the right peripherals the installation kits can be booted directly by E11 and installed on emulated disk(s).

Disk images have been successfully loaded from real PDP-11s using Kermit, or Process Software TCP/IP, or DECnet and Pathworks, or (as a last resort) an OS-supplied DUMP command on the PDP-11 with the output captured with a PC terminal program and then massaged back into binary with a simple utility program. Also, `PUTR` (available from `ftp.dbit.com`, see below) can build bootable RT-11 image files using a floppy disk distribution kit, without the need for booting a real PDP-11.

3.1 SCSI disks

The easiest way of all to move any PDP-11 OS to the PC is using a SCSI disk drive. If you were already using a PDP-11 SCSI controller, you should be able to move the disk directly over to a PC SCSI controller, and either read it into an image file (using PUTR.COM) or use it directly (using the SCSI disk support in the full version of E11). Iomega Zip and Jaz drives, and Fujitsu DynaMO 3.5" magneto-optical drives, are inexpensive and work very well with both Ersatz-11 and PUTR.COM, and they provide a cheap, fast, easy way to transfer files or whole disks between real PDP-11s and E11.

Even if the PDP-11 didn't already have a SCSI controller, it might be worth obtaining a used one if a non-trivial

amount of data must be transferred, unless the PDP-11 operating system is too old to support SCSI MSCP devices. Adding support for it to the operating system might require a SYSGEN in some cases, but for RSX, BRUSYS will support a DU: controller regardless of whether your usual monitor is built with the DU: driver. Older versions of RSTS can both backup and restore without ever booting a monitor at all, and the backups are self-booting and include a copy of the backup utility, so restoring them on the target system is easy. New versions of RSTS require that the backups be made under timesharing, but they can still be restored in INIT.SYS.

3.2 SCSI tapes

Magnetic tape can be a convenient way to import PDP-11 data to the PC, as long as a PC tape drive can be found which will read the PDP-11 media. The DEC TZ30 and TK50Z-GA SCSI drives use TK50 tapes, and a variety of companies still make SCSI 9-track tape drives. These may be mounted inside E11 as PDP-11 tape drives and used directly by the emulated PDP-11, or images may be taken using D Bit's DOS SCSI tape utility (available from ftp://ftp.dbit.com/pub/ibmpc/util/st.exe) and the resulting `.TAP` files may be mounted under E11.

3.3 Kermit

Kermit is a protocol for transferring files over serial lines. It provides very good reliability, and requires no special hardware, but it can be slow. At 9600 baud with the default Kermit protocol parameters (no long packets or sliding windows), binary file transfers can take almost an hour per megabyte. This may be acceptable if the system has small disks or the transfer can be performed over a weekend or during some other time when the PDP-11 is not busy with other work. Kermit protocol support is included in most terminal programs, and Kermit software is available at little or no cost for most computers and operating systems, including the following PDP-11 versions:

- KSERVE — D Bit's server-only Kermit for RT-11, available from `http://www.dbit.com/pub/pdp11/rt11/kserve.mac`
- K11 — Columbia's official PDP-11 Kermit program, supports all major DEC/Mentec/S&H operating systems, see `http://www.columbia.edu/kermit/pdp11.html`
- KRT — Billy Youdelman's version of K11, enhanced for RT-11 and TSX-Plus, also at `http://www.columbia.edu/kermit/pdp11.html`

It's very important to issue SET FILE TYPE BINARY commands to the Kermit programs at both ends before beginning a Kermit transfer of a PDP-11 disk. The other settable Kermit parameters are less critical, as they mainly affect the speed with which the transfer will proceed. Of the above Kermits, only KSERVE is able to download an entire raw disk. The others can download files but not entire raw disks. In some cases it may be possible to get around this limitation by using PDP-11 system utilites (such as RT-11's COPY/FILE/DEV command) to copy an entire raw disk into a file on another, larger disk, and then use Kermit to download that file. Or, if no larger disk is available, it may be possible to break the disk into several pieces (each small enough to fit into the free space on another disk) and copy them to files one at a time, sending each to the PC via Kermit and then deleting it.

3.4 Ethernet

Ethernet can be a very effective way to transfer PDP-11 data to a PC. Unfortunately Ethernet hardware is not nearly as common on PDP-11s as it is on PCs, but used Q-bus/Unibus Ethernet boards are available very cheaply

from used equipment dealers. So if the PDP-11 has software support for an Ethernet board, it may be worth buying one just to transfer the disks.

The main problem with using Ethernet on PDP-11s is the availability of compatible protocols. If a PDP-11 operating system supports Ethernet, it usually uses DECnet, while PCs are more likely to support TCP/IP. However software to support either protocol is available on both PCs and PDP-11s, it's just a matter of getting it.

- Alan Baldwin's excellent free TCP/IP packages for RT-11 and TSX-Plus are available via FTP from `shop-pdp.kent.edu`.
- Megan Gentry's "RTEFTP" RT-11 Ethernet file transfer program is available from `ftp://ftp.std.com/pub/mbg/pdp11/rt11/tools/rteftp/`. It uses its own private protocol and can communicate only with other computers running RTEFTP, however it's fast, very easy to set up, and can transfer raw disks.
- JSA Stackware, a commercial TCP/IP package for RSX, is available from JSA. It provides Telnet and FTP access in both directions.
- Process Software's TCP/IP package for the PDP-11 is also a commercial product, available from Process Software (`www.process.com`).
- DECnet/DOS and Pathworks for DOS are no longer available, but they were able to connect to DECnet hosts. So if you already have one of these packages, it may be useful for transferring disks.

Some of the above programs are not able to transfer entire raw disks over the Ethernet. In this case the same workarounds as used with Kermit transfers may be applied, to copy raw disks to files and then transfer the files.

3.5 ASCII serial dump

Most DEC operating systems provide a utility (typically named DUMP or DMP) which can dump a file or device out to the terminal in octal or hexadecimal. If this program is used to dump out the entire disk, a PC terminal program can be used to capture the output, and it can be translated back to a binary disk image on the PC. This should only be used as a last resort because there's no error checking or correction, and the transfer is very slow because of the inefficient encoding and extra header/trailer/address information that's normally displayed with each block.

If possible the transfer should be done using hexadecimal rather than octal, the transfer will go faster since each word is displayed as only four characters instead of six. On an RSX system, this can be done with the following commands:

```
>INS $DMP
>DMO ddu:/DEV/LOCK=V (if ddu: is the system disk)
>MOU ddu:/FOR (if ddu: is not the system disk)
>DMP TI:=ddu:/BL:0/WD
```

The file produced by capturing the output from the above command can be translated back into a binary disk image using the "HEX2DSK" program, available from `ftp://ftp.dbit.com/pub/ibmpc/util/`. Source code is included so the program can be modified for other dump display formats if needed. RT-11 has a DUMP/TERMINAL command, which is similar to RSX's DMP command but gives a different output format.

Since there is no error detection at all, disks transferred in this manner should be downloaded twice, and the resulting files should be compared, as a test to make sure the dump wasn't corrupted by line errors or buffer overruns.

3.6 System-specific notes

RT-11 is the easiest operating system to transplant. For one thing, an RT-11 Kermit server is available (at ftp://ftp.dbit.com/pub/pdp11/rt11/kserve.mac) which is able to download an entire raw disk image over a serial line. This can take a long time but it just about guarantees that the configuration will be duplicated exactly, just don't forget to type SET FILE TYPE BINARY and REMOTE SET FILE TYPE BINARY to make sure both participating Kermits agree not to try to treat the binary data as text. Failing that, you can use KSERVE, or any of several other file transfer methods, to download the individual files (still in binary mode) into a PC directory. Then use D Bit's "PUTR" program (available at ftp://ftp.dbit.com/pub/putr/) to build a blank RT-11 disk image, copy the files into it (be sure to use PUTR's COPY/B command to copy in binary mode), and make the disk bootable with PUTR's BOOT command.

Note

> The RT-11 `DL:` and `DM:` device handlers expect to find a bad block replacement table in block 1 of a disk. If something else is there (like the pack label in Files-11 and RDS 1.1 and later, or the master file directory in RDS 0.0), they will replace blocks at random and you'll get a corrupted disk image. So either modify your Kermit (etc.) to use the appropriate `.SPFUN` instead of `.READ`, or don't use RT-11 programs to read non-RT-11 disks.

RSTS images can be assembled from individual files using Paul Koning's freely available "flx" program, see below. All you need to build a bootable pack are the files from SY:[0,1], flx knows how to do the HOOK operation and make the pack bootable.

RSX is more difficult to move since currently there is no DOS software that knows how to build a bootable disk from its component files. If you don't have an easy way to take a raw snapshot of the whole disk (K11.TSK currently can't do it), the best bet is to dump the disk to tape and then restore the tape on the PC, assuming you have suitable tape drives on both. Stand-alone BRU (a.k.a. BRUSYS) is the easiest way to do this. After copying the entire disk to tape, build a bootable BRUSYS tape for E11 (HELP BRU STAND under RSX will tell you how). Then use PUTR.COM to build a blank disk image file of the appropriate type, and boot E11 from the BRUSYS tape, with the empty disk image file mounted. Once BRUSYS has started, you can physically switch tapes, or else pop up an E11 prompt and MOUNT the (first) backup tape if you're using tape image files. Then run FMT (if needed) and BAD on the blank disk, and finally run BRU to restore the tape. If you want to use tape image files instead of using a real tape drive (required on E11 Lite, since it doesn't support SCSI tapes), you can use D Bit's DOS SCSI tape utility (available from ftp://ftp.dbit.com/pub/ibmpc/util/st.exe) to copy between real tapes and E11 tape image files.

3.7 Utilities

`PUTR.COM`, a companion program to E11 is available from `ftp://ftp.dbit.com/pub/putr/`, and knows how to read and write RT-11 and RSTS/E and DOS/BATCH volumes on a variety of media, as well as how to read RSX volumes. It can write blank container files with the serial numbers and (empty) bad block data filled in correctly, and format many types of DEC floppies, and SCSI disks too, which can be useful with any OS. It can also read and write TU58 DECtape II tapes, if the drive is connected to a PC COM port. Assembly language source is included.

Paul Koning (former RSTS/E developer) has written a very complete program named "`flx`" for manipulating files in RSTS disk images. Among other things it can build a bootable disk given the files from [0,1]. It's available from `ftp://ftp.dbit.com/pub/flx/` and is written in portable C, so it can be used with any emulator (or with real PDP-11 disk packs on a VAX). A DOS executable is included with the sources.

Chapter 4

Disk Devices

Ersatz-11 emulates a wide variety of disk drive and controller models. These are created using one `MOUNT` command (see page 97) for each drive unit needed. Generally each emulated disk unit must be connected to an emulated disk device (e.g. a large file on the PC's disk) which is at least as large as the disk it emulates. The connection is device-independent, so any emulated disk can be connected to any of the physical disk device types that E11 supports. The controller itself is created implicitly when its first drive is mounted, and can be deleted by dismounting all of its drives. The controller type (RL11, UDA50 etc.) is implied by the device name used in the `MOUNT` command, and the same device name syntax is the same as most DEC operating systems.

E11 has sensible defaults for all disk parameters, so in most cases a `MOUNT` command for each unit is all that is needed. If necessary, the default drive parameters can be overridden using `MOUNT` switches, and the default controller parameters can be overridden using a separate `SET` command, which may be given before or after the drives are mounted. The defaults are as follows:

parameter	*default*	*how to override*
controller model	based on `SET CPU QBUS` setting	`SET` *ddc*`:` *model* (e.g. `SET DUA: RQDX3`)
controller CSR/vector	DEC default addresses "floating" addresses are calculated automatically if appropriate	`SET` *ddc*`: CSR=`*xxxxxx* `VECTOR=`*yyy*
interrupt priority	DEC default values, `SET CPU QBUS` setting	`SET` *ddc*`: PRIORITY=`*n*
drive model	based on size of container file	MSCP/TMSCP drives: `/TYPE:`*type* switch (e.g. `/TYPE:RD54`) non-MSCP/TMSCP drives: `/`*type* switch (e.g. `/RK06`)
write protection	disabled	`/WP` or `/RO` switch

A drive may be write-protected after it is mounted using a `SET` *ddcu*`: READONLY` command, and may later be write-enabled again with `SET` *ddcu*`: READWRITE`.

After a drive is mounted, a `SHOW` *ddcu*`:` command (e.g. `SHOW DUA0:`) will display the actual drive parameters for that unit, as well as the controller parameters for the controller to which it is attached. The controller CSR, vector,

interrupt priority, and type (i.e. controller model) can be changed explicitly at any time with a `SET` command. If these parameters are defaulted, their actual values can also be changed implicitly at any time, by a change in the `SET CPU` setting (which can make a defaulted controller type switch between the Unibus and Q-bus models of that controller), and by changes in the configuration of other devices that use "floating" CSRs and/or vectors (if this controller is set to be a floating device, as `DUB:` and `DYB:` normally are for example).

4.1 Disk cache

Ersatz-11 provides a built-in disk cache, which can be enabled individually for each emulated disk unit by adding a "`/CACHE`" or "`/CACHE:`*n*" switch to the `MOUNT` command that creates that unit. *n* is the amount of memory (in bytes unless an optional suffix of `KB`, `MB`, or `GB` is added) to be set aside for the cache. This number includes all variably-sized data structures, so the actual amount of data that can be held in the cache will be lower. The default is 16 MB.

The built-in cache is intended mainly for the DOS version of E11, since the older DOS disk caches don't always scale well to the available RAM and hard disk capacity on modern PCs. On Linux and Windows systems the host operating system already provides good disk caching, so there may be no advantage to using the built-in cache. Some experimentation might be worthwhile though, since using E11's cache in addition to the OS-supplied one may reduce system call overhead enough to be noticeable.

The cache is currently write-through, i.e. it does not use delayed writes. Future versions may introduce write-back caching, with a settable delay.

4.2 Padding short volumes

There are different schools of thought about what an emulator should do if a disk is being emulated using an image file (or raw real drive) which is smaller than that disk, so it's settable. One of these switches may be added to any disk `MOUNT` command:

`/NOPAD` Don't pad short images up to the size of the emulated disk. Any attempt to perform I/O beyond the end of the image file (or raw device) will give an I/O error. This is the default.

`/PAD:NULL` Pad the image up to the emulated size with null space. Reads beyond the end of the physical disk will return zeros, and writes are ignored.

`/PAD:RAM` EXPERIMENTAL FEATURE. Pad the image up to the emulated size with a partial RAM disk. This may be useful for systems which use the latter part of a disk as swap space. This is an experimental feature and may have bugs.

4.3 PC disk devices

The `MOUNT` command establishes a connection between an emulated PDP-11 disk drive unit, and a PC file or device which will be used to hold the actual disk data. Generally this file or device must be at least as large as the PDP-11 disk unit that is being emulated. E11 supports several different forms of physical media to be used for emulating disks. The connections are made on a per-unit basis so it is possible to mix units attached to different types of physical media within the same emulated PDP-11 disk controller. The supported types of physical media

are described below, along with the syntax of the MOUNT command for each type. The /RONLY (syn. /WPROTECT switch may be specified on any MOUNT command, to lock the disk against writes.

4.3.1 Disk image files

Command syntax:

MOUNT *ddcu*: [*d*:*path*\]*filename*[.DSK] [*switches*]

Special switches: none

A disk image file contains a byte-by-byte image of a PDP-11 disk, presumably loaded from a real PDP-11 using Kermit or DECnet or some equivalent, or built using PUTR.COM or FLX.EXE or RT11.EXE or a similar utility (see chapter 3). The file is the same size as the total capacity of the PDP-11 disk drive it replaces. The file is located using E11's usual search rules, see section 1.9 for details.

There are two types of image files, "block" and "sector" images. "Block" images contain the disk data as it would be read in sequential block order, which for most PDP-11 disks is the same as the raw device order. This is the most common format and is normally used by default. "Sector" images apply to floppy disks only. RX01, RX02, and RX50 disks are organized using a soft interleave layout to increase their speed when used with controllers that have only one sector buffer. The PDP-11 device handlers (and/or controllers) for these disks handle the soft interleave so it is normally invisible to the PDP-11 user program, so images made of these disks using something like the RT-11 "COPY/FILE/DEV" command will be normal block images. When a block image file is accessed as a virtual PDP-11 floppy disk, Ersatz-11 does the inverse of the soft interleave so that when the PDP-11 driver does the interleave, the blocks come out in the correct order.

However if the image is taken using special software (such as the COPFLP.MAC program available from ftp.dbit-.com), or on a non-DEC computer, it may be more natural for the image file to be in raw sector order, i.e. starting with track 0 sector 1, then track 0 sector 2, track 0 sector 3 etc. In this case Ersatz-11 should not alter the interleave, and in fact it should do the interleave itself if the file is mounted as something other than a virtual floppy drive (since PDP-11 drivers for other devices don't do the floppy-style interleave).

By default, Ersatz-11 guesses whether a file is a block or a sector image based on the file size:

size (bytes)	*type*
256,256	RX01 sector image
512,512	RX02 sector image
1,025,024	"RX03" (DS RX02) sector image
(anything else)	block image

Block images of RX01/02/03 disks are slightly smaller because the interleave scheme leaves out track 0, so they can be distinguished by size alone, unless padding was added during transfer or something else altered the file size. RX50 image files are the same size either way, since the RX50 soft interleave scheme uses all sectors of the disk. So by default they are assumed to be block images. The defaults may be overridden with the "/BLOCK" and "/SECTOR" switches on the MOUNT command.

Since DEC's 8" floppy interleave scheme doesn't use track 0, data from this track do not normally appear in a block image file. However some non-standard software may need to use track 0, so the RX11, RX211, and RXT11 emulations relocate it beyond the end of the block image, if the file is enlarged by the size of one cylinder to be the same size as the equivalent sector image file. Use "/BLOCK" to specify that it's still a block image, in spite of being the size of a sector image. In this case it may be more natural to use a sector image, but E11 supports either

scheme.

type	*base size (bytes)*	*extra size (bytes)*
RX01	252,928	3,328
RX02	505,856	6,656
"RX03"	1,011,712	13,312

If the base file sizes are used, these files work as regular block images and track 0 does not exist. Any attempt to write track 0 is a no op, and any attempt to read track 0 returns hex E5 in every data byte, as if the disk were freshly formatted.

Note

The Demo version of E11 limit the combined size of all image files to 256 MB. E11 versions prior to 2.0 did not have this restriction, but they are no longer supported by D Bit.

Disk caching done by the host system

Ersatz-11 has no control over any caching of disk writes that the host operating system may do, so it is important that you `QUIT` out of the simulator to make sure all the pseudo-disk files get closed properly, rather than simply switching the computer off, after shutting down your PDP-11 operating system. Otherwise there is the possibility that a write-back disk cache might not have written all of the PDP-11's data to disk. In practice no problems have been observed, but trouble is theoretically possible so care should be taken. The floppy disk support controls the hardware directly so as long as the PDP-11 is done with the disk it's OK to take it out of the drive.

Also, the emulator has no control over "Green PC" BIOSes or power-saving operating systems which spin down hard drives after a specified period of inactivity (this is especially common on laptops). When E11 accesses the drive after it's been shut down, the system will pause several seconds while it spins the drive back up. During this period E11 is not running, so the simulated PDP-11 may drop incoming characters (but not necessarily, E11 maintains a small FIFO buffer on each line at interrupt level) and its clock will lose a few seconds. If this is a problem you may have to disable this BIOS feature.

4.3.2 Raw SCSI disk drives

Command syntax:

`MOUNT` *ddcu*`: SCSI`[*h*][*t*][*_l*]`:` [*switches*]

parameter	*values*	*default*	*meaning*
h	`A`–`Z`	`A`	SCSI host adapter (`A` = first HA)
t	`0`–`15`	`0`	SCSI target number (`8`–`15` for wide devices only)
l	`0`–`7`	`0`	SCSI logical unit number (LUN) within target

The host adapter and LUN are normally defaulted, so for example "`SCSI6:`" refers to SCSI device 6 on the first (or only) SCSI adapter.

Special switches: `/INTERVAL:`*n* sets disk change polling interval, `/START:`*n* and `/END:`*n* define partition boundaries

Raw SCSI disks may be accessed through an ASPI manager, which is normally supplied by the SCSI controller vendor (and is loaded in CONFIG.SYS).

Removable disks, such as Iomega Zip drives or Fujitsu DynaMO magneto-optical drives, are supported as well as hard drives, and in many cases media may be interchanged with real PDP-11 SCSI drives (using controllers made by CMD and others). Note that CMD MSCP controllers on real PDP-11s are often configured to deduct one block from the reported size of the disk to allow for the RCT (relocation control table, an MSCP data structure). For compatibility with these popular controllers, E11's default operation is to do the same when mounting a raw SCSI drive as a DU: device. The "`/NORCT`" switch may be used to override this behavior.

When a SCSI drive is idle, E11 sends SCSI "TEST UNIT READY" commands at regular intervals to check for a change in online/offline/disk-change status. This is done for exact compatibility with DEC MSCP controllers, and in practice it works better than some of the aftermarket SCSI controllers used on real PDP-11s, which notice a disk change only the next time I/O is attempted on that device. The polling interval is 5 seconds by default, but it can be changed using the `/INTERVAL:`*n* switch, which changes the interval to poll every *n* seconds instead, or not to poll at all if *n* is zero.

Disks with sector sizes other than 512 bytes are supported by E11. Data are re-blocked as necessary, with read-modify-write sequences done when writing a partial sector, so the physical sector size is completely independent of the sector size of the emulated PDP-11 disk. In particular, SCSI CD-ROM drives work well (regardless of the drive model), and so do magneto-optical cartridges, some of which use 2048 bytes per sector.

Partitions

SCSI disks may be partitioned, so as to emulate multiple drives using subsets of a physical disk. This is especially useful now that many of the PC hard drives on the market are larger than the maximum size that most PDP-11 operating systems can handle. Mounting a partition is done by using the `/START:`*n* and/or `/END:`*n* switches on the `MOUNT` command, to specify the partition's starting and ending locations on the SCSI disk. The "*n*" values (which may include a decimal point) are specified in units of 512-byte blocks by default, where block 0 is the first block of the disk. Units other than 512-byte blocks may be specified by appending a suffix to the "*n*" number. The table below lists the valid suffixes. The suffix must be immediately adjacent to the number, without intervening white space.

suffix	*unit*
`BYTES`	bytes
`BLOCKS`	512-byte blocks (default)
`KB`	kilobytes (2^{10} bytes)
`MB`	megabytes (2^{20} bytes)
`GB`	gigabytes (2^{30} bytes)
`TB`	terabytes (2^{40} bytes)
`PB`	petabytes (2^{50} bytes)
`EB`	exabytes (2^{60} bytes)
`ZB`	zettabytes (2^{70} bytes)
`YB`	yottabytes (2^{80} bytes)

The units larger than "`EB`" are included for future expansion only, as Ersatz-11 is currently limited to using disks whose capacity in bytes can be expressed with a 64-bit number (i.e. below 16 EB). If `/START:`*n* is omitted, the emulated drive starts at the beginning of the disk. If `/END:`*n* is omitted, the emulated drive ends at the end of the disk. The value given in the `/END` switch is actually the first location *following* the partition, so that the difference between the `/END` and `/START` values is equal to the length of the partition. If both switches are omitted, the emulated drive uses the entire disk.

E11 does not allow partitions to overlap each other. If a `MOUNT` command would mount a partition that covers a part of the disk which is already in use by another existing mounted partition, the emulated device (or devices) already attached to the other partition(s) will be implicitly dismounted, and an informational message will be displayed for each.

If a partition is defined which begins beyond the end of the disk, no error message is given, but the emulated drive will have a size of zero bytes. Partitions are re-evaluated each time a disk change occurs in a removable drive. So, on multi-density drives whose capacity depends on the size of the disk which is inserted, partitions may be placed such that they have zero size when a small-capacity volume is mounted, but their size will become non-zero if a large-capacity disk is inserted in the same drive.

`MOUNT` examples using partitions:

`MOUNT DU0: SCSI1:`	uses entire drive
`MOUNT DU0: SCSI1: /END:4800`	uses first 4800 blocks
`MOUNT DU0: SCSI1: /START:32MB /END:64MB`	uses second 32 MB
`MOUNT DU0: SCSI1: /START:2GB`	uses from 2 GB mark up to end of volume
`MOUNT DU0: SCSI1: /START:1000BYTES /END:1GB`	OK to mix units, and endpoints need not be at physical sector boundaries

Low-level formatting

Ersatz-11 is able to perform low-level formatting of SCSI disks even while the system is running. The easiest way to do this is to make the PDP-11 think it's a floppy disk (albeit an unusually large one), using a command like `MOUNT DU1: SCSI3: /TYPE:RX33` (or `MOUNT DY0: SCSI3:`), and then use the PDP-11 operating system's utility for formatting RX33 (or RX02) floppy disks. These utilities generally don't mind if the floppy disk is the "wrong" size or takes an unusually long time to format. However when formatting what looks like an RX33 floppy, the DEC utilities typically refuse to go ahead with the format operation unless the MSCP controller is a RQDX3 or an RQZX1, so you should `SET` one of those controller types before attempting to format.

E11 also supports low-level formatting using the "write headers" commands on the `DB:`, `DK:`, `DM:`, `DP:`, and `DR:` emulations. Since SCSI devices can't be formatted piece-meal, E11 implements this by formatting the whole volume whenever the PDP-11 does a "write headers" command which starts at the beginning of the disk. All other "write headers" commands are no ops. This has the unfortunate side effect of defeating utilities which intend to skip formatting over the manufacturer's bad block list which appears on the last track of some older disk types, so PDP-11 utilities will complain that the bad block file is missing even if one had been written on the disk prior to formatting. In some cases the utilities are still willing to proceed, after performing their own surface scan to check for bad blocks.

`MOUNT SCSI:` drive switches:	
`/END:`*n*[*units*]	set end of partition (default is rest of volume)
`/INTERVAL:`*n*	set polling interval for detecting media changes
`/START:`*n*[*units*]	set start of partition (default is 0)

4.3.3 Raw BIOS disk drives and partitions

Command syntax:

`MOUNT` *ddcu*`: BIOS`[*u*][*p*]`:`

parameter	*values*	*default*	*meaning*
h	A–Z	A	BIOS disk unit (A = first disk)
t	0–255	0	FDISK partition number (0 means the entire disk)

This command mounts an entire PC hard drive (or FDISK hard drive partition) as a PDP-11 disk, using the PC's INT 13h hard disk BIOS to perform I/O. The letter "*u*" specifies which disk to use (A means the first one, B is the second, etc.), and "*p*" is the partition number, which is usually in the range 1–4 unless the disk uses an extended partition. The lettering and numbering is intended to coincide with the scheme used by Linux's "/dev/hd" device. If the partition number is 0 (or is omitted), the entire disk is used as one drive.

Entire partitions can be cumbersome to set up or move, but the performance is good since all sectors are contiguous, and the maximum size is very large so this can be an easy way to get around file system size limitations.

NOTE

> This is a brand new feature of E11 (as of V5.1) and has had very little testing. Please use it with caution, especially if the disk is shared with non-E11 partitions, since unexpected problems could result in data loss in other partitions. Make frequent backups, and don't use it at all in cases where data corruption would be unrecoverable.

4.3.4 Raw floppy disk drives

Command syntax:

SET *d*: *type* (if needed)
MOUNT *ddcu*: *d*: [*switches*]

Special switches: drive type, one of the following:

switch	*drive type*	*size in blocks*	*disk types*
/RX01	5.25" or 8" SS SD	494	RX01
/RX02	5.25" or 8" SS DD	988	RX01, RX02
/RX03	5.25" or 8" DS DD	1,976	RX01, RX02, RX03
/RX23	3.5" 1.44 MB	2,880	RX23, RX24
/RX24	3.5" 720 KB	1,440	RX24
/RX26	3.5" 2.88 MB	5,760	RX23, RX24, RX26
/RX33	5.25" 1.2 MB	2,400	RX33, RX50, "RX52"
/RX50	5.25" SS DD	800	RX50
/RX52	5.25" DS DD	1,600	RX50, "RX52"
/MY	5.25" DS DD	1,600	MY: (Russian PDP-11 clones)

Floppy disk drives may be used to emulate any block-replaceable device supported by E11. "*d*:" is the drive letter, i.e. A: or B: for the first or second floppy drive. A command switch specifies the drive type, the default type is RX23, RX24, RX26, or RX33 depending on the type set for that drive in the PC's BIOS setup. The default for each drive may be changed using a SET command, so that future MOUNT commands using that drive won't need a switch to set the floppy drive type.

For example, SET B: RX01 overrides the value in the BIOS setup, so that future MOUNT*ddcu*: B: commands will access the drive as an 8" SS SD drive. This command is normally just a convenience, however a real DEC RX50 drive (or some other quad density drive, like a Tandon TM100-4) attached to the PC floppy controller is a special case, which requires e.g. a SET A: RX50 command before use. This is because the /RX50 switch on the MOUNT command assumes the RX50 disk is mounted in a 1.2 MB drive, which turns at a different speed from a true RX50

or QD drive and thus requires a different data rate to access the same data.

As shown in the table above, most drive types support one or two smaller disk formats in addition to their own. This means that any disk type supported by a given drive type may be inserted at any time with no need to re-`MOUNT` the drive. E11 will automatically detect the format of the new disk and adjust to the new geometry. Capacity changes are passed along to emulated PDP-11 controllers that understand them, i.e. the `DU:`, `DY:`, and `HD:` controllers.

Note that confusion is possible if a floppy disk has a different total number of blocks than the device being emulated. The PDP-11 OS may try to access areas off the end of the disk, which results in a controller-specific I/O error, or may not use all of the disk. In particular writing a blank file system (with an OS-specific "initialize volume" command) will result in a directory structure that doesn't match the actual volume size. Care should be exercised to avoid trouble. Like disk types are of course not a problem, so for example "`MOUNT DX0: B: /RX01`" will mount a real RX01 disk to be used as an emulated RX01 disk. The `HD:` device works with any size device, so all floppy types may be mounted on `HD:` if you have the "HD.SYS" device handler (under RT-11).

If the disk already has a correct directory structure to match its actual size, and is mounted to emulate a device of at least that size, most operating systems (that use device-independent file system formats) will be able to read and write the disk correctly. For example, if you initialize an RX23 floppy with RT-11 directory structure using the PUTR utility under DOS, and then "`MOUNT DL0: A: /RX23`" in E11 (using the 1.44 MB RX23 disk to emulate a 5 MB RL01 pack), RT-11 will be able to access all files on the disk, and can write new files without data corruption. Only the RT-11 `INITIALIZE` and `SQUEEZE` commands need to be avoided in this case.

Most of the floppy disk formats supported by E11 are exact equivalents to PC formats. Not all of them were ever supported by DEC for use on PDP-11s in particular, but some were supported by aftermarket controllers. The RX01/02/03 formats use 1.2 MB disks, specially formatted (by E11 or the PUTR utility) to have the exact same geometry as their 8" counterparts. The RX01 format is in fact identical to the IBM 3740 format used on DEC's 8" disks, so if a Shugart style 8" drive is attached to the PC floppy disk controller using a special cable (or D Bit's "FDADAP" floppy disk adapter board, see `http://www.dbit.com/fdadap.html`), it will be possible to read/write/format real RX01 disks. DEC uses a modified MFM format for RX02 disks, which the PC hardware is incapable of using, so E11 substitutes the IBM System/34 compatible format for the RX02/RX03 workalike disks.

The RX01 format is not guaranteed to work (on either 5.25" or 8" drives) because most current PC floppy controllers don't have a working single density mode (the PC BIOS is hard-coded for double density so manufacturers have dropped support for "unneeded" features). However some floppy controller chips made by SMC, Goldstar, and Western Digital are known to work with single density mode. These chips usually contain "37C65" in the part number and use a 16/32 MHz clock plus a 9.6 MHz clock rather than the single 24 MHz clock used by many other controllers, so it may be useful to shop for a floppy controller board that has two crystals on it instead of one, in the absence of better information. The "CompatiCard IV" controller formerly made by Micro Solutions, Inc. works with single density disks and is supported by E11.

In addition to the PC formats and 8" workalike formats, E11 also supports several 5.25" formats. RX50 disks are supported using a 1.2 MB drive. "RX52" is E11's name for double-sided RX50 disks, which were never sold by DEC, but may have been planned (for the Professional series at least). "MY" is the device name for the DS DD 5.25" disks used on the Russian DVK-x PDP-11 clones. The low-level format is the same as the "RX52" but there is no software sector interleave. "MX" disks are not able to be supported by the PC disk controller so E11 can't use them.

E11 can format all the disk types that it supports. Usually the easiest way to get at this feature is using the "set density" command of the RX211 controller, which can be executed by running `FORMAT.SAV` under RT-11 (using commands like "`FORMAT DY0:`" or "`FORMAT DY0:/SINGLE`"), or the `SPEC%()` function under RSTS. E11 chooses which of the formats (supported by a given floppy drive type) to use based on the size of the emulated disk, it uses whichever format is the same size as the emulated volume being formatted, or the next larger format if there's no exact match.

Ersatz-11 also supports the "format floppy disk" commands of the RQDX3 and RQZX1 controllers, so utilities that would work with those controllers will work with E11.

4.3.5 Catweasel floppy disk drives

Command syntax:

`SET CAT`*c*`:` *bus* `PORT=`*nnn* (if needed)
`SET CAT`*cu*`:` *type* (if needed)
`MOUNT CAT`*cu*`:` *d*`:` [*switches*]

Special switches: drive type, same as for raw floppy disks

The experimental Catweasel floppy driver allows reading disks using Catweasel floppy controller boards, made by Individual Computers (www.jschoenfeld.de). These controllers access the disk at a very low level, and can access floppy formats which the regular PC hardware can't. This driver is currently read-only and does not work reliably, however some users may want to experiment with it.

4.3.6 Raw CD-ROM drives

Command syntax:

`MOUNT` *ddcu*`: CDROM`*d*`:`

Special switches: none

The CD-ROM drive whose DOS drive letter is specified by "*d*" is accessed using the DOS MSCDEX.EXE (or DR-DOS NWCDEX.EXE) driver. Note that this is a synchronous interface so PDP-11 emulation is stalled while reading from a CD. More importantly, the Windows 9x version of the MSCDEX interface refuses to access the first sixteen sectors of the disk, which are unused on ISO-9660 disks, but are needed on disks written in a PDP-11 disk format. The workaround is to use real DOS, or else use a SCSI CD-ROM drive with E11's "SCSI:" device type.

DVD-ROMs may also be accessed through the CDROM: interface.

Note that the MSCDEX.EXE (etc.) interface does not provide a way for a program to detect disk changes, which means that it is not safe to use the `/CACHE` switch with the `CDROM:` device type, because the cache has no way of knowing whether the CD has been changed and the cached data should be thrown away.

4.3.7 RAM disk drives

Command syntax:

`MOUNT` *ddcu*`: RAM:` [*switches*]

Special switches: `/LOAD:`[*d*`:`*path*\]*filename*[`.DSK`], `/SIZE:`*blocks*, `/LOW`, `/HIGH`

RAM disks may be created using regular PC memory. This gives extremely fast access to disk data, but has the disadvantage that all data are lost on shutdown. So any needed files should be copied to permanent storage before

shutting down E11, and data may be permanently lost in the event of a power failure. The maximum possible size of RAM disks depends on the amount of memory available, so the `SHOW MEMORY` command may be useful in deciding how much space to allocate. Note that the actual amount of memory needed to create a RAM disk is slightly more than the disk's raw capacity, since E11 needs to maintain internal data structures related to the RAM disk and the emulated PDP-11 controller to which it is attached.

If no `MOUNT` switches are given, a RAM disk is created that's the same size as the drive being emulated, which is itself defaulted. This size may be changed using the "`/SIZE:`*n*" switch, which sets the size of the disk to *n* blocks. Other units besides blocks may be used by appending the unit to the number (with no space in between), for example "`/SIZE:20MB`" sets the size to 20 megabytes. The RAM disk will initially contain all zeros unless it is loaded from a disk file, which is done with the "`/LOAD:`[*d*:*path*\]*filename*[`.DSK`]" switch. The file is located using E11's usual rules, see section 1.9 for details. If this switch is given, the RAM disk will be the same size as the file, unless the size is explicitly set with the "`/SIZE`" switch. The RAM disk is loaded from the file once when the MOUNT command is issued, then the file is closed. Any data written to the RAM disk do not change the file from which it was loaded. Note that if the RAM disk is not loaded from a file, it will normally need to be initialized by the PDP-11 operating system after creation, in order to have a usable file system.

The `/LOW` and `/HIGH` switches decide whether the RAM disk's memory is allocated from 32-bit address space (the low 4 GB) or 64-bit address space, respectively. The default is to use 32-bit space for RAM disks smaller than 1 GB, and 64-bit space if the requested size is larger, or if there isn't enough 32-bit memory available. RAM disks in 32-bit space work slightly faster than ones in 64-bit space, but they must be small enough to fit in whatever memory is free below the 4 GB limit of 32-bit addressing.

4.3.8 Disks with intentionally bad blocks

Command syntax:

`MOUNT` *ddcu*`: BAD:` [*switches*] *pcdev* ...

Special switches: `/LIST:`[*d*:*path*\]*filename*[`.TXT`]

This layer may be inserted in front of any other disk emulation to add known bad blocks to a disk. This may be useful for testing error support in PDP-11 utilities, or for preparing a disk image file which will later be transferred to a real disk that has bad blocks. The `/LIST` switch gives the name of a text file which contains the list of block numbers (separated by white space and/or newlines) for all the bad blocks. Any attempt to read or write those blocks will return a device-dependent I/O error through the emulated disk controller.

4.3.9 Null disk drives

Command syntax:

`MOUNT` *ddcu*`: NULL:` [*switches*]

Special switches: `/SIZE:`*blocks*

Null disks are useful only as placeholders. They appear to be the specified size (the default size matches the emulated drive type), but reads return zeros and writes have no effect.

4.4 Emulated PDP-11 disk devices

This section describes each PDP-11 disk drive type that Ersatz-11 emulates, and defines the device-specific `MOUNT` command switches that apply to each emulated disk type.

name	*units*	*controller*	*drive/volume switches*
`DB:`	0–7	RH11/RH70	`/RP04`, `/RP05`, `/RP06`, `/SERIAL:`*nnnn*, geometry switches
`DC:`	0–3	RC11	geometry switches
`DD:`	0–1	DL11	(none, always TU58 DECtape II)
`DF:` (syn. `RF:`)	0–7	RF11	geometry switches
`DK:` (syn. `RK:`)	0–7	RK11D	`/RK02`, `/RK05` (syn. `/RK03`), geometry switches
`DL:`	0–3	RL11	`/RL01`, `/RL02`, geometry switches
`DM:`	0–7	RK611	`/RK06`, `/RK07`, geometry switches
`DP:`	0–7	RP11C	`/RP02`, `/RP03`, geometry switches
`DR:`	0–7	RH11/RH70	`/RM02`, `/RM03`, `/RM05`, `/RM80`, `/RP07`, `/SERIAL:`*nnnn*, geometry switches
`DS:`	0–7	RH11/RH70	`/RS03`[`L`[`A`]], `/RS04`[`L`], geometry switches
`DT:`	0–7	TC11	(none, always TU55/TU56 DECtape)
`DU:`	0–65535	MSCP	`/TYPE:`*xxxyy*
`DX:`	0–1	RX11	geometry switches
`DY:`	0–1	RX211	`/RX01`, `/RX02`, `/SS`, `/DS`, geometry switches
`FX:`	0	Fox 2/30 DBI	geometry switches
`HD:`	0–15	virtual	(none, file size is all that matters)
`PD:`	0–1	RXT11	geometry switches
`QX:`	0–3	Terak	geometry switches

The "geometry switches" available on most models refer to `/CYLINDERS:`*n*, `/HEADS:`*n*, and `/SECTORS:`*n*, which may be used to specify non-standard drive dimensions. This is for compatibility with some clone controllers, which allowed extended (or shrunken) drive sizes and/or untranslated SMD drive geometry to be used instead of the standard DEC geometry. In some cases the PDP-11 drivers may have been patched to use the non-standard geometry. These switches allow duplicating that hardware configuration so that the patched drivers will run unchanged under E11.

4.4.1 DB: — RP04, RP05, RP06

These are top-loading 12-platter pack drives. The RP04 (built by Sperry) and RP05 (Memorex) hold about 87 MB each, and the same media can interchange between them; the only reason for the different model numbers is that they were built by different OEMs. The RP06 (Memorex 677) is a double-capacity version of the RP05, with a capacity of about 174 MB. Up to eight drives can connect to an RH11 or RH70 Massbus channel. These drives were extremely popular in the late 1970s and early 1980s, and were commonly emulated by aftermarket controllers made by Emulex, SI, etc. E11 allows the `/CYLINDERS:`*n*, `/HEADS:`*n*, and `/SECTORS:`*n* switches when mounting these drive types, to support cases where the PDP-11 drivers have been patched to support extended or untranslated drive geometries using SMD drives on aftermarket controllers. Also, the `/SERIAL:`*nnnn* switch sets the drive serial number.

MOUNT DB: drive switches:	
/CYLINDERS:*n*	set non-standard number of cylinders
/HEADS:*n*	set non-standard number of heads
/RP04	set drive type to RP04 (87 MB 12-platter pack drive)
/RP05	set drive type to RP05 (87 MB 12-platter pack drive)
/RP06	set drive type to RP06 (174 MB 12-platter pack drive)
/SECTORS:*n*	set non-standard number of sectors
/SERIAL:*nnnn*	set drive serial number (4 decimal digits)
/WPROTECT	enable write protection (syn. /RONLY)

SET DB: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
RH11	set controller type to RH11
RH70	set controller type to RH70
VECTOR=*nnn*	set vector address to *nnn* octal

4.4.2 DC: — RC11/RS64

This is a very early drive with one to four fixed platters and fixed heads yielding high speed but very low capacity (128 KB per platter). It's useful mainly as a swap device, so using a RAMdisk to emulate it is a good choice. There are few if any surviving units today, and no current PDP-11 operating system version is known to support it, although earlier versions of RSTS did, as did DOS/BATCH. Since there is only one possible drive type, no switches are required to select it.

MOUNT DC: drive switches:	
/WPROTECT	enable write protection (syn. /RONLY)

SET DC: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal

4.4.3 DD: — DL11/TU58

The TU58 is a small one- or two-transport cartridge tape drive. It is attached to the PDP-11 using a serial port, and communicates using RSP (Radial Serial Protocol), or MRSP (Modified RSP) in later drives. It uses cartridges which are physically similar to DC2000s, but hold only 256 KB each using DEC's proprietary format. DEC introduced the TU58 because they wanted to have a low-end storage peripheral which was cheap enough (well, about $1800, cheap by DEC's standards, and at least it didn't require its own controller card) that they could expect customers all to buy one. Then DEC would be able to get away with shipping diagnostics, microcode, and small software updates on just one medium, instead of having to make everything available on all types of media in use at the time. TU58s were plentiful, but deathly slow and low in capacity. DEC called the drives "DECtape II" in the hope that the name would remind customers of the earlier 555/TU55/TU56 DECtape drives, which were very popular.

TU58 drives are normally attached to a DL11/DLV11 serial line unit, and this is what DEC's OS-supplied drivers expect. However there's no reason why a TU58 can't be attached to any type of serial line, so E11 allows emulated

TU58s to be mounted on any of its emulated serial ports. This means that creating a TU58 involves two or three steps: an `ASSIGN` command to attach the `DD:` device to a serial line, and one or two `MOUNT` commands to attach block devices to TU58 units 0 and/or 1.

For example:

```
ASSIGN TT1: DDA:
MOUNT DDA0: UNIT0.DSK
MOUNT DDA1: UNIT1.DSK
```

This would attach the first TU58 controller (`DDA:`) to a DL11 port (`TT1:` appears by default at the CSR and vector addresses expected by DEC's TU58 drivers), and then attach files to each of the two transports on that TU58. The `ASSIGN` and `MOUNT` commands may be given in any order.

Note that the command to boot from this combination is `BOOT TT1:`, *not* `BOOT DDA0:`, since `TT1:` is the device whose registers must be controlled to make the drive boot. The `BOOT` command supports drive 0 only.

`MOUNT DD:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET DD:` controller parameters:	
`NEW`	new firmware (MRSP with bidirectional flow control)
`OLD`	old firmware (RSP, flow control from PDP-11 to TU58 only)

4.4.4 DF: — RF11/RS11, DDC DMS-11X/SSDM 100 (called RF: in RT-11)

The RS11 is another fixed-head disk, and is a PDP-11 version of the RS08 disk for the PDP-8. It was word-addressable and more popular than the RS64, as it was larger (512 KB) and more reliable. Due to their high speed for the time, RS11s were commonly used for swapping, so it may make sense to use a RAM disk to emulate an RS11. E11 allows write protecting the entire unit (with the `/WPROT` or `/RO` switch), but it does not emulate the RS11's switch panel which allowed write-protecting the disk in individual 32 KB segments.

The Digital Development Corporation DMS-11X controller is an extended replacement for the RF11/RS11, which uses a DDC "SSDM 100" RAM drive to hold up to 8 MB of data. It uses slightly different disk addressing from the RF11, and uses the unit select bits as additional track address bits, so only DF0: is useful. Non-zero unit numbers will not be accessible when emulating a DMS-11X controller. A full 8 MB RAM disk may be created as follows:

```
SET DF: DMS11X
MOUNT DF0: RAM: /SIZE:8MB
```

`MOUNT DF:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET DF:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`DMS11X`	set controller type to DDC DMS-11X
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`RF11`	set controller type to RF11
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.5 DK: — RK02, RK03, RK05 DECpack (called RK: in RT-11)

These front-loading cartridge drives were very popular in the 1970s thanks to their low cost and small size (a 10.5" rack-mount box). The disks are similar to the IBM 2315, and many other minicomputer manufacturers used a similar form factor. The RK02 is a rebadged Diablo model 30 (low density) drive, and holds 1.2 MB. The RK03 is a Diablo model 30 (high density) which holds 2.5 MB. The RK05 is a DEC-built media-compatible replacement for the RK03 which also holds 2.5 MB. It changes the disk-select method to support a maximum of eight RK05 drives per controller instead of just four RK03s (but can be configured to use the old scheme for compatibility with RK11C and RK8E controllers). DEC also built the RK05J, which is a later model of the regular RK05, and the RK05F, which has a fixed platter with twice as many tracks and acts like two RK05 drives. All of these drives turn at 1500 RPM.

E11 does not distinguish between the RK03 and RK05 because they have identical geometries. The RK02 is no longer supported by current versions of PDP-11 operating systems. It is unusual in that it stores 256 bytes per sector, vs. 512 for the RK03 and RK05. Be careful when using odd image file sizes with the `DK:` emulation — if you intend a disk to be used as an RK05 but it's not quite 4800 blocks long, E11 will auto-detect it as an RK02, which probably isn't what you want. Use an `/RK05` switch to be sure.

`MOUNT DK:` drive switches:	
`/RK02`	set drive type to RK02 (1.2 MB cartridge drive)
`/RK03`	set drive type to RK03 (2.5 MB cartridge drive)
`/RK05`	set drive type to RK05 (2.5 MB cartridge drive)
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET DK:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.6 DL: — RL01, RL02

The RL01 and RL02 are top-loading cartridge drives which hold 5 and 10 MB, respectively. DEC marketed them successfully as a replacement for the RK05, and they were extremely popular in the 1980s due to their reliability, small size (a 10.5" rack-mount box) and the relatively low price of the drives (however the cartridges were expensive). They turn at 2400 RPM, vs. 1500 RPM for the RK05. New RL01 and RL02 cartridges come with a bad block table written by the manufacturer in the last track, which the PDP-11 operating systems are careful never to overwrite. Some utilities check for this table and will complain if it is not present, so be sure to get the whole disk when making image files. The PUTR utility (available from `ftp.dbit.com`) knows how to write a null bad block track when creating an empty image file (using its `FORMAT ... /RL0`*x* command).

Note that the RLV12 Q-bus controller adds support for 22-bit addressing using an extra register, which makes it incompatible with DEC's floating CSR rules for the second and later controller, since the rules pre-date the RLV12's introduction and expect an RL11 or RLV11 controller to fit in four words of space on the I/O page. This can cause unexpected CSR conflicts on systems with a second RLV12 controller plus other floating devices. An explicit `SET DLB: CSR=...` command may be needed.

`MOUNT DL:` drive switches:	
`/RL01`	set drive type to RL01 (5 MB cartridge drive)
`/RL02`	set drive type to RL02 (10 MB cartridge drive)
`/WPROTECT`	enable write protection (syn. `/RONLY`)

SET DL: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
DEFAULT	set controller type to default (RL11 for Unibus, RLV12 for Q-bus)
RL11	set controller type to RL11 (Unibus)
RLV11	set controller type to RLV11 (Q18)
RLV12	set controller type to RLV12 (Q22 with BAE register)
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

4.4.7 DM: — RK06, RK07

The RK06 and RK07 are top-loading twin-platter cartridge drives with capacities of about 13 and 27 MB, respectively. They were mounted on free-standing low-boy cabinets and were sort of a poor man's Massbus drive. Even the geometry and register layouts are similar to Massbus but there are only two platters (one timing surface, three data surfaces), the disks turn at only 2400 RPM, and the control bus is serial rather than parallel. The drives could be dual-ported but this configuration was rare.

MOUNT DM: drive switches:	
/RK06	set drive type to RK06 (13 MB cartridge drive)
/RK07	set drive type to RK07 (27 MB cartridge drive)
/WPROTECT	enable write protection (syn. /RONLY)

SET DM: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal

4.4.8 DP: — RP02, RP03

These are top-loading 12-platter pack drives originally designed to be used with the PDP-10 series, but adapted for the PDP-11. The RP02 holds 20 MB per pack, while the RP03 holds 40 MB. RT-11 can't use a whole RP03 at once due to the RT-11 file structure's limit of 32 MB per volume, so it makes an RP03 look like two 20 MB disks. Although these were fairly early drives and weren't very widely used, the programming model is straightforward and as a result, aftermarket controllers that emulate them using SMD drives are common. Some of these controllers supported special drive geometries to give extended capacity and/or use the untranslated SMD sector addressing. In order to emulate these configurations, E11 supports the /CYLINDERS:*n*, /HEADS:*n*, and /SECTORS:*n* switches so that the user may specify custom disk dimensions.

MOUNT DP: drive switches:	
/CYLINDERS:*n*	set non-standard number of cylinders
/HEADS:*n*	set non-standard number of heads
/RP02	set drive type to RP02 (20 MB 12-platter pack drive)
/RP03	set drive type to RP03 (40 MB 12-platter pack drive)
/SECTORS:*n*	set non-standard number of sectors
/SERIAL:*nnnn*	set drive serial number (4 decimal digits)
/WPROTECT	enable write protection (syn. /RONLY)

SET DP: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal

4.4.9 DR: — RM02, RM03, RM05, RM80, RP07

The RMxx/RP07 series are late-model Massbus drives, and replace and upgrade the older RP04, RP05, and RP06 drives. Their capacities and programming model are slightly different from the earlier Massbus drives, so they aren't exact replacements.

The RM02 and RM03 are modified and rebadged CDC 9762 drives. Both hold 67 MB on a 5-platter pack, and media can be interchanged between the two models, as well as with unmodified CDC 9762s using Emulex controllers. The only major difference between the RM02 and RM03 is that the RM02's spindle turns at 2400 RPM rather than 3600 RPM. This was done so that the RM02 would be slow enough to work with any PDP-11 model using the RH11 Massbus adapter.

The RM03 (67 MB 5-platter pack drive), RM05 (256 MB 12-platter pack drive, actually a modified/rebadged CDC 9766), and RM80 (DEC's own 124 MB Winchester disk using the same basic drive as the R80 and RA80) were considered by DEC to be too fast for plain Unibus PDP-11s (really the problem was just the inadequate FIFOs on the RH11 Massbus adapter). Similarly, the RP07 (516 MB Winchester disk manufactured by Sperry) was supposed to be too fast for any PDP-11 to use at all, although some users managed to get them working anyway, by reformatting them to use use greater than 1:1 interleave.

As with the DB: drives, E11 allows the /CYLINDERS:*n*, /HEADS:*n*, /SECTORS:*n*, and /SERIAL:*nnnn* switches to be used when mounting DR: drives.

MOUNT DR: drive switches:	
/CYLINDERS:*n*	set non-standard number of cylinders
/HEADS:*n*	set non-standard number of heads
/RM02	set drive type to RM02 (67 MB 5-platter pack drive)
/RM03	set drive type to RM03 (67 MB 5-platter pack drive)
/RM05	set drive type to RM05 (256 MB 12-platter pack drive)
/RM80	set drive type to RM80 (124 MB Winchester drive)
/RP07	set drive type to RP07 (516 MB Winchester drive)
/SECTORS:*n*	set non-standard number of sectors
/SERIAL:*nnnn*	set drive serial number (4 decimal digits)
/WPROTECT	enable write protection (syn. /RONLY)

SET DR: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
RH11	set controller type to RH11
RH70	set controller type to RH70
VECTOR=*nnn*	set vector address to *nnn* octal

4.4.10 DS: — RS03, RS04

The RS03 and RS04 are fixed-head Massbus disks that hold 512 KB and 1024 KB, respectively. As with the RS11, these were used for swapping and other cases where speed is critical, so mounting them as RAM disks would work well.

`MOUNT DS:` drive switches:	
`/RS03`	set drive type to RS03 (512 KB fixed-head disk)
`/RS03L`	set drive type to RS03L (512 KB fixed-head disk with interleave)
`/RS03LA`	set drive type to RS03LA (512 KB fixed-head disk with interleave)
`/RS04`	set drive type to RS04 (1024 KB fixed-head disk)
`/RS04L`	set drive type to RS04L (1024 KB fixed-head disk with interleave)
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET DS:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`RH11`	set controller type to RH11
`RH70`	set controller type to RH70
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.11 DT: — TU55, TU56 DECtape

Although it's actually 3/4" magnetic tape, DECtape is block-replaceable and uses a fixed number of fixed-size blocks, so really it behaves more like disks do than tapes. It puts 578 512-byte blocks on a 260' tape, and was very popular for off-line storage in the early 1970s when hard disk space was expensive and floppy disks were not yet widely available. The TU55 is a single-transport drive, while the TU56 has two independent transports, so it takes two `MOUNT DT`*n*`:` commands to define a TU56. That difference is invisible to the PDP-11 so there's no switch to tell them apart.

`MOUNT DT:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET DT:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR6 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.12 DU: — MSCP disks

MSCP (the Mass Storage Control Protocol) is a flexible, device-independent protocol which allows any disk device (up to 2 TB) to connect to any of DEC's later computers. It was used in all of DEC's PDP-11 disk controllers from the mid-1980s on. DEC imposed an artificial limit of four drives per controller, upon which some versions of some PDP-11 operating systems depend. Also, DEC wants unit numbers to be unique within a system (i.e. if there's a unit 0 on one controller there should be no unit 0 on any other controller), and the maximum allowable unit number varies from one device type to another, depending on the method used to assign a unit number to a drive (unit select cap for the "ready" light, DIP switches, etc.). Unlike many of DEC's own drives, E11 implements the full 16-bit unit numbers specified by MSCP, so the amount of available memory is the only limit on unit numbers

or the number of drives per controller. Even so, care should be taken to observe the limitations that the PDP-11 operating system imposes on MSCP configuration.

MSCP provides a way for the PDP-11 to find out the model name of each drive, which can be one to three letters followed by two decimal digits. This is largely a cosmetic feature, since MSCP already has ways for the PDP-11 to find out a disk's size and whether it's fixed or removable, so most of the time the name is meaningless. But all the same, the drive type can be set to any appropriate string using the "`/TYPE:`*name*" switch on the `MOUNT` command. The default drive type string is "RA81" for image files, or the actual drive type ("RX50" etc.) for floppies.

In some cases the drive type is important, for example some of the programs that format floppy disks on RQDX3 and RQZX1 controllers will refuse to go ahead unless they believe that the drive is an RX33, so you should use "`/TYPE:RX33`" when mounting a floppy drive which is to be formatted using standard software.

MSCP requires that each volume (except for floppy disks) contain a relocation control table (RCT) at the end of the disk, with a minimum length of one block. This table is used for remapping bad blocks and making the volume appear to be error-free. Since all current PC disk media (except floppy disks) provide some form of invisible bad block remapping of their own, they are already error-free, so there is no real need for this feature. Some aftermarket SCSI controllers provided a one-block RCT anyway, by deducting one block from the reported size of the volume. E11 can be set to do the same thing using the `/RCT` switch. This is the default for SCSI disks, but it can be overridden using the `/NORCT` switch.

`MOUNT DU:` drive switches:	
`/NORCT`	don't deduct one block for relocation control table
`/RCT`	deduct one block for relocation control table
`/TYPE:`*xxxyy*	set drive type to *xxxyy* (1–3 letters, 2 digits)
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET DU:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`CSR=FLOATING`	set CSR address to be auto-configured
`DEFAULT`	set controller type to default (UDA50A for Unibus, RQDX3 for Q-bus)
`KDA50`	set controller type to KDA50
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`RQDX2`	set controller type to RQDX2
`RQDX3`	set controller type to RQDX3
`RQZX1`	set controller type to RQZX1
`RUX50`	set controller type to RUX50
`UDA50`	set controller type to UDA50
`UDA50A`	set controller type to UDA50A

4.4.13 DX: — RX01

The RX01 is a single sided, single density floppy disk drive which uses 8" disks with the standard IBM 3740 format, the same as was commonly used in CP/M systems. The RX01 is a dual-drive system. If only one of the two units is `MOUNT`ed, the other one will still appear to be there, since the RX11/RXV11 controller has no way of reporting whether a drive is present or not, but any attempts to do I/O to the missing drive will return error status.

E11 can read and write actual RX01 floppy disks, using an 8" drive attached to a PC floppy controller (with an adapter such as D Bit's FDADAP board) which supports single density.

MOUNT DX: drive switches:	
/WPROTECT	enable write protection (syn. /RONLY)

SET DX: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

4.4.14 DY: — RX02, "RX03"

The RX02 is a double-density follow-on product to the RX01. It holds twice as much data per disk, and also uses DMA instead of programmed I/O to copy between PDP-11 memory and the on-board sector buffer, so there's less CPU overhead. DEC apparently planned a double-sided upgrade, which became commonly know as the "RX03" but was never actually released. However, there are connectors for the extra heads on the drive's controller board (most of the "brains" of the RX01 and RX02 systems are actually in the drive), and DEC even documented the register fields that have to do with using double-sided disks, and the RT-11 V4.0 DY.MAC driver includes support (disabled under conditionals and with a bug at label DOXFER where R3 hasn't been loaded yet) for double-sided disks, but it was removed in later versions.

E11 includes the double-sided support in its emulation. The /SS and /DS switches can be used when mounting the drive to set the number of sides, and SET DY*u*: SS (or DS) can be issued at any time to change it. This may be necessary when swapping disks in a real floppy drive, because unlike 8" drives, 5.25" drives have no way of distinguishing single- from double-sided disks, so it can't be done automatically.

RSTS/E uses the names DX: and DY: interchangeably to refer to an 8" floppy drive, which may be either an RX01 or RX02. This may mean that the device name needed to emulate an existing drive under E11 is different from the name that had been used to refer to the same drive under RSTS/E.

MOUNT DY: drive switches:	
/DS	double-sided disk
/RX01	single-density disk
/RX02	double-density disk
/SS	single-sided disk
/WPROTECT	enable write protection (syn. /RONLY)

SET DY: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
DS[1]	disk in drive is double-sided
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
SS[1]	disk in drive is single-sided
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

[1]Really a drive option — unit must be mounted before this option is set

4.4.15 FX: — Fox 2/30 "drum"

The Foxboro Company's Fox 2/30 process control system was based on a PDP-11/15 CPU but used a Foxboro-specific "data bus interface" (DBI) to connect Foxboro's own hardware to the CPU over a private bus. One of these devices was a Digital Development Corporation 6200 or 7311 fixed-head disk (or SSDM 100 RAM disk) which the Foxboro documentation calls a "drum", probably because some of the control electronics are inside the disk shroud, which leads it to be much taller than is usual for a disk. The disk was available in several configurations, with a varying number of tracks (64, 96, 128, 144, and 256 are known possibilities), each containing 242 sectors of 32 bytes each. There's only one disk so it must be FX0:, and the size of the image file decides how many tracks exist. The FX1: device is used to emulate the Foxboro paper tape reader.

The SET CSR value for the FX: device is the base address of the DBI, normally 164000. E11 emulates the registers for FX0: or FX1: or both (depending on whether they've been MOUNTed), but doesn't get in the way of other DBI registers in case the real DBI is connected to E11 through a Unibus adapter. The register at 164000 contains status bits for each of the devices plugged into the DBI. E11 emulates this register as needed, and if a Unibus adapter is present, it combines the emulated status bits with the ones from the real DBI.

`MOUNT FX:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET FX:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR7 for Unibus, BIRQ7 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.16 HD: — Hypothetical disk

This is a hypothetical disk device which exists only in Ersatz-11. Its original definition was based on reverse-engineering the `HD_SYS.EXE` device emulation that came with the so-called "Russian" LSI-11/2 emulator which used to be floating around the Internet, so that E11 would be able to boot disk images intended for that emulator. However that emulation was not very useful, since it (apparently) had no provision for interrupts or memory beyond 64 KB or drives bigger than 32 MB. The current emulation has been extended to support 22-bit addressing, up to 16 drives of up to 2 TB each, and it uses interrupts to signal completion so the system doesn't have to stall during I/O. The main reason it's interesting is that it supports variably sized devices like MSCP does, but with a much simpler programming model so that PDP-11 drivers can be written which require far less memory than MSCP drivers. An RT-11 driver (HD.MAC) is included with E11, and one for Fuzzball is available from `ftp.dbit.com`.

`MOUNT HD:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET HD:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.17 PD: — PDT-11/150 RX01

The RXT11 single-density 8" floppy controller in the PDT-11/150 microcomputer (see Appendix E) is just different enough from the RXV11 to be incompatible with regular RX01 software, so E11 provides it as a separate emulated controller type.

`MOUNT PD:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET PD:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

4.4.18 QX: — Terak 8510/a single-density disk

The Terak 8510/a's single-density 8" floppy controller uses media compatible with the DEC RX01, but has a different programming model. Multi-controller boot blocks detect the controller type by looking for a boot PROM, so there must be a ROM image at location 173002 containing something other than 000340 for booting to work.

`MOUNT QX:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET QX:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

Chapter 5

Tape Devices

The full range of standard PDP-11 magtape drives and controllers can be emulated under Ersatz-11. Tape drives are configured in the same way as disks, with a `MOUNT` command to set up each emulated tape unit. The defaults for controller and drive parameters also work the same way as disks, with the controller model based on the emulated CPU type and the CSR and vector computed according to "floating" address rules if necessary. However the default tape drive models are essentially chosen arbitrarily, since unlike disks, there's no point in trying to guess the drive model based on the size of the PC file or device that's being used to emulate a tape drive, because the amount of data on a tape is variable anyway. In any case, the default drive and controller parameters can be overridden with `MOUNT` switches and `SET` commands, the same way they can with disks. The `/RONLY` (syn. `/WPROTECT` switch may be specified on any `MOUNT` command, to lock the tape against writes.

A drive may be write-protected after it is mounted using a `SET` *ddcu*`: READONLY` command, and may later be write-enabled again with `SET` *ddcu*`: READWRITE`.

5.1 Experimental tape cache

Ersatz-11 has a built-in cache for caching tape writes. Like the disk cache, it is enabled by adding a "`/CACHE`" or "`/CACHE:`*n*" switch to the `MOUNT` command, and again the default is a 16 MB cache. Unlike the disk cache, the tape cache's purpose is to speed up writes, not reads. SCSI tapes normally buffer all write commands so they appear to complete in a very short time. Then when a tape mark is written, they catch up with all outstanding writes, so the write-tape-mark operation can take a very long time. Many PDP-11 drivers use timeouts to detect broken hardware, and they will report errors on these slow write-tape-mark operations.

The tape cache works around this problem by guaranteeing, as long as the cache isn't full, that the various types of "write" operations will complete within a certain amount of time. If the physical tape drive gets behind, then the cache will store written data in memory until the tape drive catches up, reporting the (fake) completion of each write command just as its time quota expires. Normally the tape drive will catch up quickly, since the problem with modern SCSI tapes is only with the latency of certain commands, not with the overall average speed. In extreme cases where the drive really is much slower than the DEC 9-track drive it replaces, it may be necessary to define a very large cache to ensure that timeouts never occur.

NOTE

The tape cache has passed all internal testing at D Bit, but as it is a new feature (as of V5.1) with an

unproven record in the outside world, we recommend that it be used only when necessary to prevent timeouts. If possible, make duplicate copies of tapes in .TAP files until you are confident that the tapes are reliably coming out the same as the files.

Note that because the cache works by reporting successful completion to the PDP-11, of write operations that haven't completed yet and may not even have started, write errors and/or end-of-tape status may not be reported at the expected time. When an error occurs in a delayed write, the cache starts a 30-second timeout. If the PDP-11 attempts more tape I/O during that period, the cache returns the error in response to the new I/O operation. If not, a message (which includes ASCII BEL characters to attract attention) is displayed on the console (TT0:). The error message is also stored so that it will be included in the output from the `SHOW` command for the emulated PDP-11 tape unit which had the error. This makes it possible to see the specific type of error if it has scrolled off the screen.

Similarly, the cache may not find out about end-of-tape status until after it has already told the PDP-11 that the write completed without EOT status. There is no way around this if the first time the EOT marker is seen is during a write from cache, so multi-volume backups may not be possible because the EOT status won't be reported until some number of records after the actual EOT marker, by which time there may not be enough space left before the physical end of tape to finish off the volume. However, once the cache has seen the EOT marker on a given tape, it remembers its position (i.e. the number of records and/or tape marks from BOT to where the EOT marker was reported by the drive) and automatically reports EOT status on delayed writes if they are after this position. This will be reliable unless the tape is backspaced and rewritten with differently-sized records so that the number of records and/or tape marks from BOT to EOT is substantially different from what it was the first time EOT was detected. In any case this all refers only to writing, reading is done in real time so the EOT status always comes straight from the drive.

The cache has defaults for the maximum time allowed for each type of operation, which can be modified with additional switches to the `MOUNT` command to match the expectations of a specific PDP-11 tape driver. Each switch specifies the maximum amount of time (in milliseconds) which that operation may appear to take to execute. Setting a parameter to 0 disables caching for that operation, so it will occur in real time and the cache will report completion whenever the physical tape drive does.

tape command	*switch*	*default value*
Erase 3" gap	`/ERASE:`*n*	5000
Write record	`/WRITE:`*n*	5000
Write tape mark	`/WTM:`*n*	1000

5.2 PC tape devices

As with disks, E11 uses a device-independent interface to connect any emulated tape drive to any real tape device. This connection is made with a `MOUNT` command, and the current configuration of an emulated tape can be displayed with a `SHOW` command.

5.2.1 Tape image files

Command syntax:

`MOUNT` *ddcu*`:` [*d*`:`*path*`\`]*filename*[`.TAP`] [*switches*]

Special switches: `/MAXRECORD:`*n*

A tape image file contains a byte-by-byte image of tape data, with headers and trailers on each record to maintain the blocking data from the real tape. Each record looks like this:

```
.LONG   LEN     ;32-bit record length, LSB first, byte-aligned
.BLKB   LEN     ;LEN bytes of data
.LONG   LEN     ;the length again, for backspacing
```

A tape mark appears as a single 32-bit 0. The `MOUNT` command for an image file may include a `/MAXRECORD:`*n* switch, which sets the maximum possible record length that can be read or written on that unit. The default is 65536 bytes. E11's memory usage may be decreased slightly by using a smaller number, but data will be lost if the PDP-11 attempts to read or write records larger than the specified maximum. Both ANSI and DOS-11 labeled tapes normally have a maximum record length of 512 bytes, but BRU tapes and UNIX "tar" tapes use longer records. As with disks, there are also `/RONLY` (syn. `/WPROTECT`), and `/RW` switches, to optionally write lock a tape drive. The file is located using E11's usual rules, see section 1.9 for details. If the file does not exist, it is created as a zero-length file in the current working directory.

5.2.2 Raw SCSI tape drives

Command syntax:

`MOUNT` *ddcu*`: SCSI`[*h*][*t*][`_`*l*]`:` [*switches*]

parameter	*values*	*default*	*meaning*
h	`A`–`Z`	`A`	SCSI host adapter (`A` = first HA)
t	`0`–`15`	`0`	SCSI target number (`8`–`15` for wide devices only)
l	`0`–`7`	`0`	SCSI logical unit number (LUN) within target

Special switches: `/INTERVAL:`*n* sets tape change polling interval

Raw SCSI tape drives may be accessed through an ASPI manager, the same as with SCSI disks. Almost any tape drive that allows variable-length records may be used, including SCSI 9-track drives. There is specific support (i.e. workarounds for firmware bugs) for DEC TZ30 or TK50Z-GA drives, which can read and write TK50 tapes. 4 mm DAT tapes work very well, as do DLT tapes, since they have the same semantics as 9-track and TK50 tapes (but much higher capacity). Older DEC/Quantum DLT drives can even read TK50 tapes.

Some SCSI tape drives (such as 8 mm drives, and Travan cartridge drives) do not allow data to be appended to an existing tape, except at the point immediately after the very last write. This is incompatible with the ANSI and DOS-11 tape labeling schemes usually used by PDP-11s, which normally end a tape with two tape marks, and then add files to the tape by backspacing to the point between the two tape marks (if not further) and writing new file headers. These tape drives may be used only in cases where there will be no need to append additional files to the tape after it is written, for example when making a backup of an entire disk into a single save set.

As with raw SCSI disks, E11 sends SCSI "TEST UNIT READY" commands to tape drives at regular intervals to check for a change in online/offline/tape-change status. The polling interval is 5 seconds by default, but it can be changed using the `/INTERVAL:`*n* switch, which changes the interval to poll every *n* seconds instead, or not to poll at all if *n* is zero.

5.2.3 RAM tape drives

Command syntax:

`MOUNT` *ddcu*`: RAM:` [*switches*]

Special switches: `/LOAD:`[*d*:*path*\]*filename*[`.TAP`], `/SIZE:`*blocks*

RAM tapes may be created using regular PC memory, just like RAM disks. Use `SHOW MEMORY` to see how much memory is available, E11 uses 1 MB (1,048,576 bytes) by default but a different number of blocks may be specified using the "`/SIZE:`*n*" switch. Other units besides blocks may be used by appending the unit to the number (with no space in between), for example "`/SIZE:100MB`" sets the size to 100 megabytes. As with RAM disks, the actual amount of memory needed to create a RAM tape is slightly more than the tape's raw capacity, due to overhead for internal data structures. The memory allocated is shared between tape data and record length information, so data stored in many short records will require more memory than the same amount of data stored in a few larger records.

The RAM tape will initially be empty unless it is loaded from a tape image file, which is done with the "`/LOAD:`[*d*:*path*\]*filename*[`.TAP`]" switch. The file is located using E11's usual rules, see section 1.9 for details. If this switch is given, the RAM tape will be the same size as the file, unless the size is explicitly set with the "`/SIZE`" switch. The RAM tape is loaded from the file once when the MOUNT command is issued, then the file is closed. Any data written to the RAM tape do not change the file from which it was loaded.

5.2.4 Null tape drives

Command syntax:

`MOUNT` *ddcu*`: NULL:` [*switches*]

Special switches: none

Null tapes are useful only as placeholders. Writes have no effect, and reads return tape marks.

5.3 Emulated PDP-11 tape devices

This section describes the emulated PDP-11 tape drive models, and defines the device-specific `MOUNT` command switches that apply to each.

name	*units*	*controller*	*drive/volume switches*
`CT:`	0–1	TA11	(none, always TU60 DECassette)
`MM:`	0–7	RH11/RH70, TM03	`/TE16`, `/TU45`, `/TU77`, `/SERIAL:`*nnnn*
`MS:`	0–7	TS11 etc.	(none, always matches controller)
`MT:`	0–7	TM11	(none, software can't tell)
`MU:`	0–65535	TMSCP	`/TYPE:`*xxyy*

5.3.1 CT: — TU60 DECcassette

The TU60 was designed to provide cheap off-line storage using ordinary audio cassette tapes. The TU60 is a 51/4" box containing two tape transports and most of the control electronics, connected by a ribbon cable to the TA11 controller, which is an M7892 quad SPC containing a dumb interface.

Under the CAPS-11 cassette programming system, the TA11/TU60 could be used as the system's only mass storage

device. It uses programmed I/O rather than DMA, so tape data bytes are transferred one at a time. Unlike other tape devices, the TU60 requires the PDP-11 to know the record length ahead of time when reading a record, and gives an error if the PDP-11 attempts to read more or less than the correct number of bytes. The "`LOG CT`*n*`:`" command may be used to find out whether a PDP-11 program is trying to read the wrong record size.

The TA11/TU60 cassette tape system requires a mandatory load point gap (i.e. tape mark) on all tapes. E11 simulates this internally so that the load point gap does not appear on the physical medium. This allows the emulated TU60 general access to tapes that may have been created using some other device (or emulated device), where an extra tape mark at BOT would violate the labeling standards.

`MOUNT CT:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET CT:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR6 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

5.3.2 MM: — TE16/TU16, TU45, TU77

These tapes all use the TM02 or TM03 Massbus tape formatter to control up to eight slaves. The formatter itself uses one of the eight possible Massbus unit numbers (typically 0), and the resulting two-level unit selection scheme slightly complicates the device naming, since it appears nowhere else. As a result, the most common naming convention for "`MM`*n*`:`" device names uses the unit number *n* to refer to the slave number within the single formatter, rather than the Massbus unit number (which is what is referred to by the unit number with all Massbus disks), and the formatter is Massbus unit 0.

E11 uses an extended `MM:` device name syntax similar to that used by RSX, where each slave's device name looks like "`MM`*cu*`_`*s*`:`". *c* is a letter indicating which RH11/RH70 controller connects to the TM03 formatter. The default in this version of E11 is "`C`", the letter may change in future versions but in any case it refers to the default tape Massbus adapter at (17)772040. *u* is the Massbus unit number of the formatter, which defaults to 0 and is in the range 0–7. *s* is the slave number (within a TM03 formatter) of the tape transport, which also defaults to 0 and is in the range 0–7. If a number is present but no "`_`", that number is the slave number, not the Massbus unit number.

The effect is that if the controller letter and Massbus unit number are omitted leaving a device name like "`MM3:`", this name has the same meaning as the usual RT-11 or RSTS name, which is: default tape RH11 (the one at (17)772040), default formatter (0), slave 3. Meanwhile additional fields may be supplied to identify any of the 64 possible slaves on any of the (currently 3) possible Massbusses, so "`MMA2_5:`" refers to the first RH11, TM03 formatter 2, slave 5. This same name format may also be used in any other E11 command (e.g. `BOOT`, `LOG`) that takes a device name.

The `MOUNT MM:` command has switches to identify the drive model, but their only effect is to set the value of the "drive type" register. From a PDP-11 software point of view, all drives attached to a TM03 formatter look the same, the only difference is speed. There is also a `/SERIAL:`*nnnn* switch, which sets the value of the "drive serial number" register.

MOUNT MM: drive switches:	
/SERIAL:*nnnn*	set drive serial number (4 decimal digits)
/TE16	set drive type to TE16 (45 IPS NRZI/PE)
/TU45	set drive type to TU45 (75 IPS NRZI/PE)
/TU77	set drive type to TU77 (125 IPS NRZI/PE)
/WPROTECT	enable write protection (syn. /RONLY)

SET MM: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
RH11	set controller type to RH11
RH70	set controller type to RH70
VECTOR=*nnn*	set vector address to *nnn* octal

5.3.3 MS: — TK25, TS04, TS05, TU80

These drives are microcomputer-controlled and have a programming model which is like a simplified version of TMSCP. There are no drive type switches because each controller model supports only one drive type anyway, so the drive type can be controlled implicitly by changing the controller type with a SET command. The TK25 is a cartridge tape, while the others are 9-track magtapes, but they all look similar from the PDP-11 operating system's point of view.

DEC's earlier controllers support only one drive per controller so PDP-11 operating systems normally use the unit number to distinguish between separate controllers. Like later controllers, E11 allows up to 8 units per controller, so E11 uses the controller letter to distinguish between multiple controllers, the same as with most other device types. This means that when emulating a typical DEC system with one unit per controller, drives that the operating system calls MS0:, MS1:, and MS2:, will be called MSA0:, MSB0:, and MSC0: by E11, since they're the first and only slaves on three separate controllers. This issue arises only when there is more than one MS: style tape drive, which is rare.

MOUNT MS: drive switches:	
/WPROTECT	enable write protection (syn. /RONLY)

SET MS: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
DEFAULT	set controller type to default (TU80 for Unibus, TSV05 for Q-bus)
EXTFEAT	enable extended features
NOEXTFEAT	disable extended features
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
TQK25	set controller type to TQK25 (Q22 TK25 controller)
TS11	set controller type to TS11 (Unibus TS04 controller)
TSU05	set controller type to TSU05 (Unibus TS05 controller)
TSV05	set controller type to TSV05 (Q22 TS05 controller)
TU80	set controller type to TU80 (Unibus TU80 controller, M7454 module)
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

5.3.4 MT: — TS03, TU10

The TU10 is a vacuum column tape drive which interfaces to the PDP-11 through a classic Unibus interface, made up of a number of flip chip modules on a wire wrap backplane. The TS03 (actually a rebadged Kennedy 9700) is a very small tension-arm drive which uses up just 10.5" of height in a rack, and uses a physically smaller controller made with higher density modules. However they both look the same to software, so there are no drive type switches to distinguish them. The 7-track version of the TU10 is not supported.

`MOUNT MT:` drive switches:	
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET MT:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

5.3.5 MU: — TMSCP tapes

TMSCP (the Tape Mass Storage Control Protocol) is a device-independent protocol for connecting arbitrary tape drives to any of DEC's later computers. It doesn't particularly reduce the amount of implementation-specific quirks that must be dealt with (tapes never had anywhere near the amount of device-specific details as disks do to begin with), but it provides symmetry with the MSCP protocol for disks, and some systems are able to capitalize on this by sharing code between the disk and tape drivers. DEC generally didn't have more than one tape drive per TMSCP controller, but as with MSCP disks, E11 has no such artificial limits. However this means it may be possible to configure a system which is incompatible with the PDP-11 operating system's TMSCP driver, so it is best to define a separate controller for each drive anyway.

As with MSCP disks, the `/TYPE:`*xxxyy* switch sets the unit type name, which may be up to three letters and up to two decimal digits. The default is TU81.

`MOUNT MU:` drive switches:	
`/TYPE:`*xxxyy*	set drive type to *xxxyy* (1–3 letters, 2 digits)
`/WPROTECT`	enable write protection (syn. `/RONLY`)

`SET MU:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`CSR=FLOATING`	set CSR address to be auto-configured
`DEFAULT`	set controller type to default (KLESI for Unibus, TQK50 for Q-bus)
`KLESI`	set controller type to KLESI (Unibus TU81 controller)
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`TQK50`	set controller type to TQK50 (Q22 TK50 controller)
`TQK70`	set controller type to TQK70 (Q22 TK70 controller)
`TUK50`	set controller type to TUK50 (Unibus TK50 controller)

Chapter 6

Serial Lines

E11 has flexible support for serial and line printer devices. As with disks and tapes, any supported PC serial device may be used to emulate any emulated PDP-11 character device, and once again E11 chooses sensible defaults for the controller types and CSR/vector addresses based on the emulated CPU type and the configuration of "floating" devices, so in many cases no `SET` commands will be needed.

Each serial line is created with an `ASSIGN` command. `TT0:`, the system console, is connected to `CON1:` (the first emulated VT100 session, displayed on the PC video display) when E11 starts up, but it can be reassigned to any other screen or serial port with an `ASSIGN TT0:` command. If it is assigned to an RS232 serial port, the E11 prompt can no longer be popped up using Shift-Enter, because this key combination does not correspond to any ASCII character that could be sent over a serial line. So by default, a BREAK condition on the console serial port will bring up the "`E11>`" prompt. If this is inconvenient, the `SET BREAK` command can be used to define one ASCII character which will cause the prompt to pop up. For example, putting a `SET BREAK 20` command in the E11.INI initialization file will make the prompt pop up whenever CTRL/P is typed on the console terminal.

Output to any serial or printer device can be captured to a PC file using E11's `LOG` command. For example, `LOG TT0: FOO` will cause all data displayed on the console terminal to be saved in FOO.LOG, until logging is turned off with a `LOG TT0:` command (with no filename).

An `ASSIGN` command will fail if the specified PC port doesn't exist, or if the device's currently `SET` IRQ is already in use and not `SHARE`d, or if the new `ASSIGN` command would steal `TT0:`'s device for some other port. There must always be something attached to `TT0:` since that's E11's console terminal.

Note that Ersatz-11 does not flag an error if the `ASSIGN` command assigns a `TT:` port to a printer, or assigns an `LP:` port to a screen, even though these are usually not likely to be useful combinations. The reason both port types use the same pool of devices is so that they can both access COM ports, since serial terminals and serial printers are both reasonable devices. `LP:` ports attached to serial ports or video screens respond to `XON/XOFF` flow control. One good reason to `ASSIGN` an `LP:` port to a VT100 session is that a `LOG` command will capture the output to a

file, and there's no need to actually pop up that session and see it on the screen.

6.1 PC serial devices

name	*units*	*type*	*switches*
`CON`*u*`:`	1–12	video console	`/SIZE:`*W*`x`*H*
`COM`*u*`:`	1–16	PC COM port	`/FIFO[:`*n*`]`, `/NOFIFO`, serial options
`LPT`*u*`:`	1–8	PC LPT port	
`SBMIDI:`	none	Sound Blaster MIDI port	
`SCC`*cu*`:`	0–1	Sealevel sync/async	serial options
`TELNET`*c*`:`	none	built-in Telnet servers	
`TELSINGLE:`	none	built-in Telnet servers	
`TELCLIENT:`	none	built-in Telnet clients	
`ASYNC`*n*`:`	0–n	shorthand for available real serial ports	
`PRINT`*n*`:`	0–n	shorthand for available real printer ports	
`SYNC`*n*`:`	0–n	shorthand for available real sync ports	
`NULL:`	none	host-OS-independent null device	

6.1.1 Serial options common to all devices

E11 has a set of "serial options" which are common to all serial device types, and are used to set communications parameters. These options may be used as either a switch (with a preceding "`/`" character) on the `ASSIGN` command when the port is created, or as a separate `SET` command any time thereafter. For example:

```
ASSIGN TT1: COM2: /MODE:1200,N,8,1
SET TT1: MODE=2400,E,7,1
```

The first command will create TT1: and attach it to COM2. The line parameters are set to 1200 baud, no parity, 8 data bits, and one stop bit. The second command will change the existing TT1: port to use 2400 baud, even parity, 7 data bits, and one stop bit. The option name may be separated from its parameters by either a "`:`" or "`=`" character.

Note that some emulated port types allow the communications parameters to be set by the PDP-11 operating system. E11 allows this by default, but in some cases the user may want to override the PDP-11's parameters, for example to set a port to a higher baud rate than the PDP-11 equivalent supports. In this case the `/LOCK` switch will be useful when creating the port (usually in combination with a `/MODE` switch). The `SET` *ddcu*`: LOCK` and `SET` *ddcu*`: UNLOCK` commands can be used to lock and unlock the port's communications parameters after the port has already been created.

The device-independent serial `ASSIGN` switches are as follows:

`/CD:`*value* Sets the value of the CD (carrier detect) modem status signal, as seen by the PDP-11 port. *value* may be `ON` or `OFF` to force CD to appear permanently asserted or deasserted, regardless of the value actually detected by the emulated PDP-11 port. Or, *value* may be `CD` (which is the default setting), to make emulated PDP-11 port's CD input follow the actual value of the CD pin received by the PC port.

`/CTS:`*value* Sets the value of the CTS (clear to send) modem status signal, as seen by the PDP-11 port. *value* may be `ON` or `OFF` to force CTS to appear permanently asserted or deasserted, regardless of the value actually detected by the emulated PDP-11 port. Or,

value may be `CTS` (which is the default setting), to make emulated PDP-11 port's CTS input follow the actual value of the CTS pin received by the PC port.

`/DSR:`*value* Sets the value of the DSR (data set ready) modem status signal, as seen by the PDP-11 port. *value* may be `ON` or `OFF` to force DSR to appear permanently asserted or deasserted, regardless of the value actually detected by the emulated PDP-11 port. Or, *value* may be `DSR` (which is the default setting), to make emulated PDP-11 port's DSR input follow the actual value of the DSR pin received by the PC port.

`/DTR:`*value* Sets the state of the DTR (data terminal ready) modem control signal. *value* may be `ON` or `OFF` to force DTR to be permanently asserted or deasserted, regardless of the value selected through the emulated PDP-11 port. Or, *value* may be `DTR` (which is the default setting), to make the real DTR pin track the value of the emulated DTR signal from the emulated PDP-11 port.

`/LOCK` Locks communication mode parameters (baud rate, data bits etc.) against being changed by the PDP-11 port. This is useful for setting a port that has programmable parameters (e.g. a DZ11 line) to a non-standard speed without having the PDP-11 operating system set it back to a lower speed when initializing the emulated side of the port.

`/MODE:` *bps*`,`*par*`,`*dbits*`,`*sbits* Sets communication mode parameters to the values specified. *Bps* is the number of bits per second (the range of allowable values depends on the specific serial hardware). *Par* is the parity specified as one letter: Even, Odd, None, Mark, Space (not all serial hardware supports all types). *Dbits* is the number of data bits, generally 5–8 although some PC port types can only do 7–8. *Sbits* is the number of stop bits, 1–2 (on most ports, "2" actually means 1.5 if *dbits* is 5).
If no `/MODE` switch is specified, newly ASSIGNed ports are initialized by default to 9600 baud, no parity, 8 data bits, 1 stop bit, i.e. `/MODE:9600,N,8,1`.

`/RI:`*value* Sets the value of the RI (ring indicator) modem status signal, as seen by the PDP-11 port. *value* may be `ON` or `OFF` to force RI to appear permanently asserted or deasserted, regardless of the value actually detected by the emulated PDP-11 port. Or, *value* may be `RI` (which is the default setting), to make emulated PDP-11 port's RI input follow the actual value of the RI pin received by the PC port.

`/RTS:`*value* Sets the state of the RTS (request to send) modem control signal. *value* may be `ON` or `OFF` to force RTS to be permanently asserted or deasserted, regardless of the value selected through the emulated PDP-11 port. Or, *value* may be `RTS` (which is the default setting), to make the real RTS pin track the value of the emulated RTS signal from the emulated PDP-11 port.
Some newer modems use the RTS signal incorrectly to mean "ready to *receive*," and if it is not asserted they will refuse to send data to the PC. The `/RTS:ON` switch circumvents this problem. Other possible solutions include using a specially wired modem cable to hold RTS asserted, or using the `AT&R1` modem command to change the modem's behavior.

`/SRD:`*value* This switch is included for completeness only. It works like the `CD` (etc.) switch, but it controls the SRD signal (secondary receive data), which is pin 12 on a Bell 202 modem. This signal is rarely used and is not supplied by any of the supported PC serial devices, but this switch makes it possible to force the signal to appear to be active if needed.

`/STD:`*value* This switch is included for completeness only. It works like the `/DTR` and `/RTS` switches, but it controls the STD pin (secondary transmit data), which is pin 11 on a Bell 202 modem. Since none of the supported PC serial devices drives this pin, the switch has no visible effect.

`/TTSYNC` Enables XON/XOFF flow control for output from the PDP-11.

`/TXMAX:`*n* This switch sets the maximum number of transmitted characters that will be buffered for transmission by that port. Once the port has accepted this number of characters

from the PDP-11, it waits for all of them to be transmitted before accepting more characters. This value should be set low enough to get acceptable response to XON/XOFF characters (it may take up to *n* characters for the PDP-11 to react and suspend output), but high enough to get adequate throughput. The default value is 16. LA120 teleprinters are particularly sensitive to XON/XOFF response time, so they require a low `/TXMAX` value.
`TXMAX:`*n* is available only as an `ASSIGN` switch. It may not appear in a `SET` command.

`/UNLOCK` The opposite of the `/LOCK` switch, unlocks the port's `/MODE` parameters so that they may be altered by the PDP-11 port (on port types where this is possible such as the DZ11 and DHU11). This is the default so there's normally no reason to use it as an ASSIGN switch, however it may be useful as a SET keyword once the port has been assigned.

The sections that follow describe each physical PC serial (or serial-like) device that E11 supports, along with the command syntax needed to use them as emulated PDP-11 serial ports. As with disk and tape units, the ports are created on a line-by-line basis so there is no need to use the same kind of physical port for all emulated ports of a given type. Also, serial multiplexers can be sparsely populated. Only one port needs to be created for the whole emulated multiplexer to exist. Missing ports will simply throw transmitted data away and will never receive any input.

6.1.2 Video consoles

Command syntax:

`SET CON`*n*`: SIZE=`*W*`x`*H* (if needed)
`SET CON`*n*`:` *termtype* (if needed)
`ASSIGN` *ddcu*`: CON`*n*`:` [*switches*]

Special switches: `/NODOUBLE`, `/NOREPLY`, `/SIZE:` *W*`x`*H*

The specified PDP-11 terminal port is connected to one of twelve simulated VT100s, that can normally be put up on the screen by pressing Alt and the function key corresponding to the screen number (F1–F12).

The default terminal type is a VT100 with the advanced video option (AVO) installed. Available terminal types are `VT100` (the default), `VT100_NOAVO` (a VT100 with no AVO), `VT101` (like `VT100_NOAVO` but with slightly different autowrap behavior), and `VT102` (like `VT100` but with a third style of autowrap behavior, as well as a few new commands, mainly for inserting/deleting characters and lines).

Note that the screens assigned to F11 and F12 are not accessible on the old 84-key AT keyboard, unless other keys are redefined to reach them. When one screen is being displayed on the PC screen, the others (up to 11) are maintained invisibly in memory, so they will be up to date whenever another Alt/F*n* keypress switches the screen to display one of the hidden sessions. This is only the default behavior of the function keys. If they are redefined using `DEFINE KEYPRESS` commands then other keys will need to be defined to switch displays, using the "`PRIMARY` *n*" and "`SECONDARY` *n*" keyscript commands.

If there are two video adapters on the PC (e.g. an SVGA and a Hercules monochrome card), then one VT100 session may be displayed on each. Using the default keyscripts, the Alt-function keys choose which of the 12 possible screens is displayed on the primary monitor, and the Ctrl-function keys choose which is on the secondary monitor. Note that it is not possible to display the same session on both monitors at once. If this is attempted then whichever monitor was previously showing that session, switches to displaying the lowest-numbered available screen which is not already being displayed.

/NODOUBLE disables the display of double-wide or double-high characters. On an EGA/VGA/SVGA in text mode, E11 will allocate pairs of unused character-generator cells for defining double-size versions of regular characters, but there aren't enough unused cells for every possible character so this works well only when only a small number of double-sized characters are displayed (or actually, when there aren't too many *different* characters on the screen at once, which is usually not a problem with login banners etc.). When the available cells are exhausted, regular-sized characters are used, and the resulting mixture can be difficult to read. /NODOUBLE forces the display to use only regular-sized characters (double-spaced as needed) to prevent this.

The /NOREPLY switch means that this emulated VT100 should not transmit any automatic replies to control sequences sent by the PDP-11. This can be handy if you're using the "multiple physical ports" feature and want to make sure that only one of the ports answers when you do something like "SET TERM/INQUIRE".

The /SIZE:*W*x*H* switch sets the size of the text screen to *W* columns by *H* lines. E11 chooses the available text mode which is closest to this requested size. The actual text modes available on this system depend on the display adapter(s), and may be displayed with SHOW VIDEO. If a video mode other than the standard IBM modes is requested while E11 is running in a Windows DOS box, E11 will call the VESA SuperVGA BIOS to switch modes, and Windows will switch the window to full-screen because Windows's VGA emulation does not include VESA modes. The selected window size applies to what would normally be a VT100 in 80-column mode. If the emulated VT100 receives the escape sequence to switch to 132-column mode, E11 will attempt to find a video mode which is the same height but 65% wider. If no such mode is available, E11 will take the closest fit, which may be the same one from before the change. In any case, a session created with /SIZE:132x24 is not the same as an 80-column VT100 which is initially in 132-column mode. Sending ESC [?3l to this session will not switch it to 80-column mode.

The SET CON*n*: SIZE=*W*x*H* command sets the default screen size for all future ASSIGN commands on that unit. It may still be overridden by a /SIZE switch on that ASSIGN.

CON*n*: is the only device that may be used with the "VT:" VT11 vector graphics display processor, or with the "VR:" VT30 raster graphics processor. Rather than running as an emulated VT100 in text mode the way true serial devices do, VT11 sessions run in graphics mode and require an SVGA card with at least 1 MB of memory. See section 9.15 for details. The same goes for the "VR:" VT30 raster graphics display emulation. However, it doesn't need the 1024x768 graphics mode so it also works on an EGA or VGA card.

6.1.3 COM ports

Command syntax:

SET COM*n*: PORT=*nnnn* IRQ*n* (if needed)
ASSIGN *ddcu*: COM*n*: [*switches*]

Special switches: /NOFIFO, /FIFO, /FIFO:*n*

The PDP-11 port is connected to the specified PC COM port. Any changes to the default I/O port address and IRQ settings must be made with a SET COM*n*: PORT=*nnnn* IRQ*n* command before assigning a PDP-11 port to the COM port. The default values for each port, including most 16550A-style PCI serial ports, are obtained from the BIOS when E11 starts up. The baud rate, number of data bits, etc. for a COM port may be set with a /MODE switch, see section 6.1.1 for more information. These parameters may also be changed using a SET command once the port is assigned to a PDP-11 device.

The "/NOFIFO," "/FIFO," and "/FIFO:*n*" switches control usage of the receive FIFOs on the 16550A (etc.) UART chips used in almost all current PC COM ports. These FIFOs greatly reduce interrupt traffic and enabling them normally increases the maximum throughput of the system, however they can make input appear "bursty,"

especially at low baud rates. "/NOFIFO" disables the receive FIFOs, "/FIFO" enables them, and "/FIFO:*n*" enables them only when the baud rate is at least *n*. The setting is "/FIFO:4800" by default for ports that have FIFOs, ports that don't are always set to "/NOFIFO" regardless of the switch given.

SET COM*n*: controller parameters (must be issued before the ASSIGN that uses this port):	
IRQ*n*	set IRQ number (0–15)
PORT=*nnnn*	set I/O port address to *nnnn* hex
SHARE	enable ISA IRQ sharing (must come after IRQ*n*)

The default IRQ for COM ports is IRQ4 if the I/O port address is 300 (hex) or more, or IRQ3 for 2FF (hex) or less. These defaults have been traditional since IBM XTs were the standard, and most multi I/O boards will be set up this way. However it's not uncommon with newer boards for COM3 to use IRQ5 and COM4 to use IRQ2 (or IRQ9 really, which is effectively the same on an AT) by default.

6.1.4 PC line printer port

Command syntax:

SET LPT*n*: [PORT=*nnnn*] [IRQ*n*] [NOIRQ] [[NO]BIOS] [DATAPRODUCTS] (if needed)
ASSIGN *ddcu*: LPT*n*: [*switches*]

Special switches: none

The PDP-11 port is connected to the specified PC LPT port. The default port addresses for the LPT ports, including PCI printer interface boards, are obtained from the BIOS when E11 starts up. Any changes to these default I/O port address and IRQ settings must be made with a SET LPT*n*: PORT=*nnnn* IRQ*n* command before assigning a PDP-11 port to the LPT port. Some LPT ports do not work well with interrupts. For example, if there are multiple ISA LPT ports they may all try to drive IRQ7 at once, or it's possible that a printer may not generate the ACK signal correctly. In many cases this problem can be circumvented by using the SET LPT*n*: NOIRQ command before assigning the port. This tells E11 to use timers and polled I/O for printer output, which works well with most late model printers. However some older printers with less buffering may experience very poor performance with this setting, printing only one or two dozen characters per second. With these printers it is best to resolve the IRQ problem and use interrupts.

Printers may also be accessed using the PC BIOS, by issuing a SET LPT*n*: BIOS command before assigning the port. This is mainly useful for remote printing using network software that captures BIOS output and forwards it to a network print server. For a locally attached printer it's better to use the default NOBIOS setting.

The SET LPT*n*: DATAPRODUCTS command supports line printers which use the Data Products parallel interface, typically using a special cable which connects the LPT port to a 50-pin Winchester connector. When this command is in effect, E11 implements the Data Products signal polarities and protocol using software polled I/O. The very first line printed may contain a junk character, since the DATA STROBE signal is held asserted by the PC BIOS until E11 takes over.

The special cable should connect the data lines straight through, the Centronics $\overline{\text{STROBE}}$ signal is connected to DATA STROBE, and the Centronics BUSY signal is connected to DATA REQUEST. You can make the cable yourself, or you can buy a model EYN328 cable from Black Box Corporation, and connect it to the end of a regular PC printer cable by using a gender changer which has two 36-pin female Centronics connectors.

Connector pinouts for SET LPT*n*: DATAPRODUCTS:

signal	*DB25*	*Centronics*	*Winchester M/50*
DATA STROBE	1	1/19	j/m
DATA0 (LSB)	2	2/20	B/D
DATA1	3	3/21	F/J
DATA2	4	4/22	L/N
DATA3	5	5/23	R/T
DATA4	6	6/24	V/X
DATA5	7	7/25	Z/b
DATA6	8	8/26	n/k
DATA7 (MSB)	9	9/27	u/w
DATA REQUEST	11	11/29	E/C

Paired pins are signal/return. The DB25 connector doesn't have enough ground pins to have one for each signal pin, so you should connect all of DB25 pins 18–25 to the return signals from the other connector.

Regardless of the access method, LPT output is passed transparently, so you'll need to make sure that your OS and printer agree on whether lines end in <CRLF> or just <LF>, and on whose responsibility it is to expand tabs and form feeds.

`SET LPT`*n*`:` controller parameters (must be issued before the `ASSIGN` that uses this port):	
`BIOS`	use BIOS calls for I/O instead of driving hardware directly
`DATAPRODUCTS`	use Data Products protocol instead of Centronics
`IRQ`*n*	set IRQ number (0–15)
`NOBIOS`	use E11's internal driver for I/O instead of BIOS calls
`NOIRQ`	use polled I/O instead of interrupts
`PORT=`*nnnn*	set I/O port address to *nnnn* hex
`SHARE`	enable ISA IRQ sharing (must come after `IRQ`*n*)

6.1.5 Sealevel ports based on Zilog Z8530/Z85230 (E)SCC USART

Command syntax:

`SET SCC`*c*`:` [`PORT=`*nnnn*] [`IRQ`*n*] (if needed for ISA boards)
`ASSIGN` *ddcu*`:` `SCC`*cu*`:`

Special switches: none

The `SCC:` driver is for synchronous/asynchronous ports based on the Zilog Z8530 SCC or Z8520 ESCC chips. Currently this means:

- Sealevel ACB 56 (ISA)
- ACB-MP.LPCI (PCI)
- ACB-232.LPCI (PCI)

`SET SCC:` controller parameters (must be issued before the `ASSIGN` that uses this port):	
`IRQ`*n*	set IRQ number (0–15)
`PORT=`*nnnn*	set I/O port address to *nnnn* hex
`SHARE`	enable ISA IRQ sharing (must come after `IRQ`*n*)

6.1.6 Sound Blaster MIDI port

Command syntax:

`SET SBMIDI:` [`PORT=`*nnnn*] [`IRQ`*n*] (if needed)
`ASSIGN` *ddcu*`: SBMIDI:` [*switches*]

Special switches: none

The PDP-11 port is connected to the MIDI port on a Creative Labs Sound Blaster 16 compatible sound board. This allows connecting electronic musical instruments (synthesizers, etc.) to the sound board using a special cable. The default I/O port address and IRQ settings are taken from the `BLASTER` environment variable, 330/IRQ5 are used if this variable is not defined. Any changes to these defaults must be made with a `SET SBMIDI: PORT=`*nnnn* `IRQ`*n* command before assigning a PDP-11 port to the MIDI port. The communications parameters are not changeable on a MIDI port.

The Sound Blaster MIDI port supports interrupt-driven I/O only when receiving characters, so E11 must use polled I/O to transmit. This means that PDP-11 emulation may stall for up to one character time while the port driver is waiting to start a new character transmission, so the SBMIDI: port should not be used on systems where there are other real-time tasks running. This has nothing to do with emulated interrupts provided for PDP-11 software, those work in both directions, but transmitting a character can stop all PDP-11 instruction execution for several hundred microseconds.

`SET SBMIDI:` controller parameters (must be issued before the `ASSIGN` that uses this port):	
`IRQ`*n*	set IRQ number (0–15)
`PORT=`*nnnn*	set I/O port address to *nnnn* hex
`SHARE`	enable ISA IRQ sharing (must come after `IRQ`*n*)

6.1.7 Telnet servers

Command syntax:

`SET TELNET`*c*`:` [`BANNER=`[*d*`:`*path*`\`]*filename*[`.TXT`]] [`INTERFACE=`*if*] [`PORT=`*n*] [`TERMINAL=`*type*] (if needed)
`ASSIGN` *ddcu*`: TELNET`*c*`:`

Special switches: none

The PDP-11 port is connected to the host side of an internal Telnet server, which is built into Ersatz-11. This allows users to connect their terminals to the emulated PDP-11 over the Internet using a Telnet client, which appears to the PDP-11 as a regular serial port.

Each Telnet server can have an arbitrary number of PDP-11 ports assigned to it. Incoming Telnet connections are assigned to free PDP-11 ports, out of the pool which were attached to that Telnet server with `ASSIGN` commands. The ports are chosen based on the order in which the `ASSIGN` commands were given, so that a new connection will go to the earliest unused port.

By default, E11 Telnet servers are set up to receive connections on TCP port 23 (the Telnet port), on all interfaces. Both of these parameters can be changed with `SET` commands before the first `ASSIGN` which refers to that Telnet server. An interface name of "`*`" means to accept connections on any interface. Setting a specific interface name (e.g. "`eth0`") makes the server listen for connections on that interface only. The TCP port number may be set to any non-zero value. It is important to make sure that no existing server in the system already owns that port number. Otherwise the `ASSIGN` command will fail when trying to bind the port number to the port.

Normally there is no reason to use more than one Telnet server, so all of the relevant `ASSIGN` commands may have `TELNETA:` on the right-hand side (or just `TELNET:` for short, since `A` is the default). E11 provides multiple ports in case calls to one address/port should go to one pool of serial ports, and calls to another address/port should go to another.

The "`SET TELNET: BANNER=...`" command may be used to specify the name a text file which contains a login banner. This banner is displayed to all incoming connections, when they first connect. `SET TELNET: NOBANNER` disables any login banner which has been set (which is the default condition).

The "`SET TELNET: TERMINAL=`*type*" command tells E11 to negotiate with the Telnet client to use the specified terminal type, in cases where the client is a terminal program which can emulate multiple terminal models. The default is `DEC-VT100`, which is the official RFC-designated name for the DEC VT100 terminal, but many systems (notably those based on Unix) don't bother to follow this specification and use their own names for terminal types. This command allows you to set whatever name the client will understand. `SET TELNET: NOTERMINAL` disables terminal type negotiation.

`SET TELNET`*c*`:` controller parameters (must be issued before the first `ASSIGN` that uses server *c*):	
`BANNER=`*file*	set login banner
`PORT=`*n*	set server to listen on TCP port number *n*
`TERMINAL=`*type*	choose terminal type *type*

6.1.8 Single-port Telnet servers

Command syntax:

`ASSIGN` *ddcu*`: TELSINGLE:` [*switches*]

Special switches: [`/BANNER:`[*d*`:`*path*`\`]*filename*[`.TXT`]] [`/INTERFACE:`*if*] [`/PORT:`*n*] [`/TERMINAL:`*type*]

This is a single-line version of the `TELNET:` device. It's mainly useful when each PDP-11 line needs to have its own port number so that a given client always connects to a particular PDP-11 line, instead of taking the first available out of an emulated modem pool. The switches have the same meanings as the `TELNET:` device's `SET` keywords.

6.1.9 Telnet clients

Command syntax:

`ASSIGN` *ddcu*`: TELCLIENT:` [*switches*]

Special switches: [`/DESTINATION:` *IP address*] [`/PORT:`*n*] [`/TERMINAL:`*type*]

The `TELCLIENT:` device makes the PDP-11 port act as a Telnet client, initiating a connection to a remote Telnet server. The switches set the destination IP address (required) and port number (default is 23), as well as the reported terminal type. If the connection attempt fails or a successful connection closes, it is retried after a short delay, indefinitely, so that it will work even if the PDP-11 starts up before an external terminal server has booted.

6.2 PC serial pseudo-devices

This section describes pseudo-device layers which may be configured to modify the behavior of E11's actual serial port drivers.

syntax	*type*	*switches*
`HAYES:` *pcdev*:	Hayes AT command set	
`KERMIT:` *pcdev*:	Kermit client	`/ESCAPE:`*nnn*
`THROTTLE:` *pcdev*:	speed limiter for a PC port	`/RXDELAY:`*n* `/TXDELAY:`*n*
dev_1 + dev_2 + ... + dev_n	multiple PC ports	

6.2.1 Hayes-compatible dialup modems

Command syntax:

`ASSIGN` *pdp11dev*`:` `HAYES:` *pcdev*`:` [`/`*pcswitches*]

The `HAYES:` pseudo-device adds a layer in front of a data-leads-only modem which understands the Hayes "AT" command set, and makes it appear to use the normal RS232 control and status lines. Hayes-style modems were very popular on personal computers but were generally not supported by PDP-11 operating systems, which expect something more like a Bell 212A which gives call progress and ringing status using RS232 signals and responds to the DTR signal to answer and drop calls.

The `HAYES:` layer interprets the ASCII messages from the modem and makes them appear as status signals (CD, RI, etc.), sends commands to the modem when needed in response to changes in the DTR signal from the PDP-11, and inserts delays between consecutive "`+`" characters sent by the PDP-11 to prevent putting the modem in "command" mode by accident.

If a DN11 auto-dialer is attached to a device that includes `HAYES:`, any dialing commands the dialer processes are sent to the modem.

6.2.2 Kermit file-transfer protocol

Command syntax:

`ASSIGN` *pdp11dev*`:` `KERMIT:` [`/ESCAPE:`*nnn*] [`/NOSCOPE`] [`/SCOPE`] *pcdev*`:` [`/`*pcswitches*]

`KERMIT:` adds a Kermit file-transfer client to a terminal line. It works the same way as the `KERMIT` command at the "`E11>`" prompt, but it may be added to any serial line (not just the console terminal).

The `/ESCAPE:`*nnn* switch gives the octal ASCII code for the character which escapes from pass-through mode to the Kermit prompt. The default is 35 (CTRL/]). Expressions are accepted, so `/ESCAPE:'O&77` may be a slightly easier way to remember how to set up CTRL/O as the escape character, for example. `/SCOPE` (default) and `/NOSCOPE` set the editing style, so that rubout characters will be handled correctly on video or hardcopy terminals, respectively.

6.2.3 Throttled I/O

Command syntax:

`ASSIGN` *pdp11dev*`: THROTTLE:` [`/RXDELAY:`*r*] [`/TXDELAY:`*t*] *pcdev*`:` [*/pcswitches*]

The `THROTTLE:` pseudo-device adds a throttle to another serial device, setting a limit on the rate at which characters are transmitted and/or received. It is an intermediate layer between an emulated PDP-11 port and an actual PC port, and this is reflected in the command syntax used to configure it. In the `ASSIGN` command, the `THROTTLE:` keyword and its switch(es) go between the emulated PDP-11 device name and the physical PC port name.

The `ASSIGN` command as shown above creates a PDP-11 serial device and connects it to a PC serial device, and times all I/O to ensure that transmitted characters go out at least t milliseconds apart, and that received characters are seen by the PDP-11 hardware at least r milliseconds apart. The `/RXDELAY` and `/TXDELAY` switches are both optional. If either is omitted then serial data pass at full speed in the corresponding direction.

6.2.4 Multiple physical ports on one emulated line

Command syntax:

`ASSIGN` *ddcu*`:` dev_1 `+` dev_2 `+ ... +` dev_n

A single emulated PDP-11 serial line may be connected to two or more physical serial ports (as described in section 6.1), by giving multiple physical port names in the `ASSIGN` command, separated by plus sign (`+`) characters. Any data transmitted over that PDP-11 port will be copied to all of the physical ports. Input received on any of the physical ports will be mixed together and will go in the PDP-11 port's receiver. Similarly, the emulated modem control signals will be driven in all of the physical ports, however incoming modem status signals will be sampled only on the first port (dev_1).

The physical port names may be any mixture of PC serial devices. In most cases there is no reason to connect two physical ports to the same emulated port so this feature will not be used by most users, but it can be useful for logging purposes or to provide duplicate command terminals so that a system may be controlled from more than one place. The `/NOREPLY` switch may be useful on `CON`*n*`:` sessions, in order to prevent E11's VT100 emulation from replying to a "what-are-you" escape sequence, in cases where the emulated line is shared with a real terminal which will try to reply simultaneously.

Example:

```
ASSIGN TT1: COM1: + CON2:
```

This command will connect TT1: (the second emulated DL11 port) to both COM1: (the first PC serial port) and CON2: (the video session which can be popped up with Alt/F2). Output sent to TT1: will appear on both COM1: and CON2:, and input typed at either port will be received by TT1:.

6.3 Emulated PDP-11 serial devices

This section describes each PDP-11 serial device type emulated by Ersatz-11.

name	*units*	*controller*	*notes*
LP*u*:	0–3	LP11/LPV11	
TT*u*:	0–15	DL11/DLV11	KB*u*: and YL*u*: are synonyms
XU*u*:	0–1	DU11/DUV11	
YZ*cu*:	0–7	DZ11/DZQ11/DZV11	

6.3.1 LP: — LP11, LPV11 line printer ports

These ports connect a single line printer, using device registers which look similar to the transmitter half of a DL11/DLV11 serial line unit. They normally use a Data Products compatible parallel interface to connect to the printer. Converter boxes are available from Black Box Corporationto allow connecting such a line printer to a PC RS232 serial port.

SET LP: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
MODE=*b*,*p*,*d*,*s*	set communications parameters
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal

6.3.2 TT: — DL11, DLV11 single serial line units

These are the standard single-line serial ports. Every PDP-11 has at least one, which is used for the console terminal. By default Ersatz-11 connects the console terminal to CON1:, which is the same VT100 session that E11 uses for its own command prompt. The DLV11J 4-line serial card actually appears to software as four separate DLV11 ports, so it can be configured in E11 using four ASSIGN commands.

SET TT: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
DL11A	set controller type to DL11A/DL11B/KL11
DL11E	set controller type to DL11E
MODE=*b*,*p*,*d*,*s*	set communications parameters
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

6.3.3 XU: — DU11, DUV11 single serial line units

The DU11 (M7822 quad Unibus SPC) and DUV11 (M7951 quad Q-bus board) are serial line units, which generally act like DL11/DLV11 ports except that they also have some synchronous capabilities, which are currently only partly supported by Ersatz-11.

SET XU: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
MODE=*b*,*p*,*d*,*s*	set communications parameters
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

6.3.4 YZ: — DZ11, DZQ11, DZV11 4/8-line serial multiplexers

This series of boards is essentially a compressed version of the old DJ11 multiplexer. Some confusion about port numbering is possible because the early non-FCC Unibus cabinet kits supported 16 lines even though the DZ11 boards only had 8 lines each, so it takes two boards to drive all 16 lines of the distribution panel. This is outlined below:

model	*interface*	*distribution panel*
DZ11A	RS232	16 lines, only 8 work
DZ11B	RS232	none, adds 8 more ports to DZ11A
DZ11C	20 mA	16 lines, only 8 work
DZ11D	20 mA	none, adds 8 more ports to DZ11C
DZ11E	RS232	DZ11A + DZ11B (16 working lines)
DZ11F	20 mA	DZ11C + DZ11D (16 working lines)

The Q-bus versions (DZQ11 and DZV11) support only 4 lines instead of 8. The DZQ11 is a newer dual-height version of the quad-height DZV11.

SET YZ: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
DEFAULT	set controller type to default (DZ11 for Unibus, DZQ11 for Q-bus)
DZ11	set controller type to DZ11 (Unibus, 8 lines)
DZQ11	set controller type to DZQ11 (Q-bus, 4 lines)
DZV11	set controller type to DZV11 (Q-bus, 4 lines)
LOCK	lock MODE settings against changes by PDP-11
MODE=*b*,*p*,*d*,*s*	set communications parameters
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
UNLOCK	unlock MODE settings
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

6.3.5 PT: — PDT-11/130 TU58

This is the not-quite-DLV11 serial port used for the TU58 cartridge tape drive in a PDT-11/130 microcomputer (see Appendix E). The port differs from a regular DLV11 port in that the "receive" register at base+2 and the "transmit" register at base+6 are combined into a single read/write register at base+2. The normal usage of this device is to "ASSIGN PT0: DD:" to attach it to a TU58 controller, and then use "MOUNT DD*n*:" commands to set up one or both TU58 units.

SET PT: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
MODE=*b*,*p*,*d*,*s*	set communications parameters
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal

Chapter 7

Network Devices

Ersatz-11 emulates several types of network interfaces. Once again each emulated port is created with an `ASSIGN` command, and is connected to a real PC Ethernet port.

DECnet is very demanding in its use of Ethernet hardware. In order to avoid needing an address resolution protocol layer, it modifies the port's Ethernet address to incorporate the protocol address, and it also makes use of multicast addressing features. These capabilities are rarely used with protocols other than DECnet, and D Bit has found that many drivers supplied by hardware vendors appear to have been tested and debugged only against TCP/IP (v4) stacks. The calls that have to do with multicast address lists and changing the Ethernet address may not work properly, and at worst may crash the system when called.

In many cases there are several different packet drivers available for the same board so if you run into trouble, an Internet search may turn up a better driver for your board. E11's built-in NE2000, AMD PCnet-PCI, RealTek RTL8139, RealTek RTL8169, DEC Tulip, and VIA Velocity drivers have been tested extensively and support all needed features, including setting the Ethernet address, maintaining the multicast address list, and controlling the filters for the promiscuous and receive-all-multicasts modes.

Extensive logging is available for network devices. When applied to Ethernet interfaces, the `LOG` command can log any combination transmitted data, received data, and device commands.

Each network port is created by an `ASSIGN` command:

`ASSIGN` *pdp11dev*`:` *pcdev*`:` [*switches*]

This creates a PDP-11 network device named *pdp11dev*: (see valid PDP-11 device names below), which communicates with the real network using the specified PC network port.

The *switches* are usually defined by the individual PC network device drivers, but the `/LOCK` and `/MAC:`*aa-bb-cc--dd-ee-ff* switches are common to all PC network devices. `/LOCK` locks the port against letting the PDP-11 change its Ethernet address. Allowing the Ethernet address to be changed causes problems with some external network drivers and/or protocol stacks. DECnet requires this ability though. `/MAC` specifies an Ethernet address to use as the port's default, instead of the value stored in its address PROM.

The DELUA/DEUNA and DELQA/DEQNA interfaces can boot the PDP-11 over the network from a MOP Load Server. This is initiated with the `BOOT XE`*n*`:` and `BOOT XH`*n*`:` commands. These interfaces can also make the PDP-11 boot from the network or a local device when triggered remotely (e.g. with DECnet's `NCP TRIGGER NODE` *node* command), if this is enabled with a `SET` *ddu*`: BOOT=`*ddcu*`:`[`/`*os*] command.

7.1 PC network devices

name	*type*	*switches*
`NE2000`*c*`:`	NE2000 clone	`/LOCK`, `/MAC`
`PCNET`*c*`:`	AMD PCnet-PCI	`/LOCK`, `/MAC`
`PKTD:`	Packet Driver	`/INT:`*vv*, `/LOCK`, `/MAC`
`RTL8139`*c*`:`	RealTek RTL8139-based PCI board	`/LOCK`, `/MAC`
`RTL8169`*c*`:`	RealTek RTL8169-based PCI board	`/LOCK`, `/MAC`
`TULIP`*c*`:`	DEC/Intel Tulip-based PCI board	`/LOCK`, `/MAC`
`VELOC`*c*`:`	VIA Velocity-based PCIe board	`/LOCK`, `/MAC`
`UDP:`	Tunneling over UDP	`/LOCK`, `/MAC`
`NULL:`	none	host-OS-independent null interface

7.1.1 ETH*n*: — shorthand for other interface names

`ASSIGN` *ddu*`: ETH`*n*`:` [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: (depend on actual port driver used)

`ETH`*n*`:` is shorthand for any of the other network drivers listed below. Each port that E11 is able to auto-detect is assigned an `ETH`*n*`:` nickname which may be used in `ASSIGN` commmands in place of the actual device-dependent name. This means that on systems which have only one supported Ethernet port, "`ETH0:`" will work. Otherwise, `SHOW NICS` lists the possibilities.

7.1.2 NE2000: — NE2000 and compatibles

Command syntax:

`SET NE2000`*c*`:` [`ISA`] [`PCI`] [`AUTO`] [`PORT=`*nnnn*] [`IRQ`*n*] (if needed)
`ASSIGN` *ddu*`: NE2000`*c*`:` [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: `/LOCK /MAC:`*aa*-*bb*-*cc*-*dd*-*ee*-*ff*

The "`NE2000`*c*`:`" device refers to a Novell NE2000 (or compatible) Ethernet board, accessed using E11's own internal driver. This requires much less software overhead than using a DOS packet driver, and common PCI boards (such as those based on the RealTek RTL8029 chip) are supported as well as the older ISA ones. The "*c*" parameter is an optional letter specifying which NE2000 board to use (default is "A", meaning the first or only one). The port/IRQ values and controller type should be set with "SET NE2000c: ..." commands prior to issuing the ASSIGN command, except for PCI NE2000 clones where E11 obtains the port/IRQ values from the PCI BIOS. By default the controller type is "AUTO", which means that E11 should first try to locate a PCI board and failing that, should assume that there's an ISA board located at the specified port/IRQ values. Setting the controller type to "PCI" tells E11 that it's definitely a PCI board, so the port/IRQ values are ignored (the values obtained from the PCI BIOS are used instead), and an error message is given if no PCI board exists. A controller type of "ISA" tells E11 to skip the PCI probe and definitely use the supplied port/IRQ values.

SET NE2000*c*: controller parameters (must be issued before the ASSIGN that uses this board):	
AUTO	auto-detect ISA vs. PCI port type (default)
IRQ*n*	set IRQ number (0–15)
ISA	port type is ISA (or PCMCIA), use IRQ/PORT settings
PCI	port type is PCI, obtain board information from PCI BIOS
PORT=*nnnn*	set I/O port address to *nnnn* hex
SHARE	enable ISA IRQ sharing (must come after IRQ*n*)

7.1.3 PCNET: — AMD PCnet-PCI

Command syntax:

ASSIGN *ddu*: PCNET*c*: [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: /LOCK /MAC:*aa-bb-cc-dd-ee-ff*

This driver is for NICs based on the AMD PCnet-PCI series of chips (Am79C970 or similar), or PCnet-compatible emulated NICs available in some virtual machine supervisors.

7.1.4 PKTD: — Packet drivers

Command syntax:

ASSIGN *ddu*: PKTD: [*switches*] [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: /INT:*nn*, /LOCK /MAC:*aa-bb-cc-dd-ee-ff*

The PKTD: device uses a DOS Packet Driver to access the physical Ethernet board. If specified, "/INT:*nn*" gives the hexadecimal 80x86 interrupt vector to which the packet driver is attached. If the interrupt vector is not given, then the range of vectors from 20 to FF (hex) is searched until a packet driver is found that isn't already in use by another simulated Ethernet port. A list of hex 16-bit *DIX* protocol numbers, up to ten total, may be specified in network byte order (e.g. IP is 0800), in which case E11 asks the packet driver to pass only frames of those types. This may allow E11 to coexist with other protocol stacks running on the same PC, as long as they each use different sets of protocol numbers and neither one needs to change the port's physical address after the other is loaded, and in any case it may be helpful for shielding the PDP-11 operating system from unwanted broadcast traffic.

DECnet requires the ability to change the address (it wants the physical address to be based on the protocol address to avoid the additional overhead of performing address resolution over the network, as TCP/IP does), so in general running DECnet under E11 will require either that no other network software be running on the same interface, or that you install a second Ethernet board for E11's exclusive use. This is because the packet driver refuses to change the physical address once the board is already in use so as not to surprise protocol stacks that were already running when the change was made and thought they knew their own address.

Freeware packet drivers for a wide variety of Ethernet interfaces are available via anonymous FTP from many sources including ftp.crynwr.com, and are typically included on the driver disk that comes with the adapter. Ersatz-11 requires packet drivers that conform to version 1.09 or later of the packet driver specification as published by FTP Software.

7.1.5 RTL8139: — RealTek RTL8139-based PCI Ethernet boards

Command syntax:

`ASSIGN` *ddu*`: RTL8139`*c*`:` [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: `/LOCK /MAC:`*aa*-*bb*-*cc*-*dd*-*ee*-*ff*

The "`RTL8139`*c*`:`" device controls a 10/100 MBPS PCI Ethernet card based on the RealTek RTL8139 series of chips, using E11's internal driver. The "*c*" parameter is an optional letter specifying which RTL8139 board to use (default is "A", meaning the first or only one).

7.1.6 RTL8169: — RealTek RTL8169-based PCI Ethernet boards

Command syntax:

`ASSIGN` *ddu*`: RTL8169`*c*`:` [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: `/LOCK /MAC:`*aa*-*bb*-*cc*-*dd*-*ee*-*ff*

The "`RTL8169`*c*`:`" device controls a 10/100/1000 MBPS PCI Ethernet card based on the RealTek RTL8169 series of chips, using E11's internal driver. The "*c*" parameter is an optional letter specifying which RTL8169 board to use (default is "A", meaning the first or only one).

7.1.7 TULIP: — DEC/Intel Tulip-based PCI Ethernet boards

Command syntax:

`ASSIGN` *ddu*`: TULIP`*c*`:` [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: `/LOCK /MAC:`*aa*-*bb*-*cc*-*dd*-*ee*-*ff*

This driver is for NICs based on the DEC/Intel Tulip series of chips (DC21140 etc.), or Tulip-compatible emulated NICs available in some virtual machine supervisors.

7.1.8 VELOC: — VIA Velocity-based PCIe Ethernet boards

Command syntax:

`ASSIGN` *ddu*`: VELOC`*c*`:` [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: `/LOCK /MAC:`*aa*-*bb*-*cc*-*dd*-*ee*-*ff*

This driver supports NICs based on the VIA Velocity series of Ethernet chips (VT6130).

7.1.9 Ethernet tunneling over UDP

Command syntax:

`ASSIGN` *ddu*`: UDP:` *localport aaa*`.`*bbb*`.`*ccc*`.`*ddd*`:`*remoteport* [*proto*$_1$ *proto*$_2$ *proto*$_3$ ...]

Special switches: `/LOCK /MAC:`*aa*`-`*bb*`-`*cc*`-`*dd*`-`*ee*`-`*ff*

This pseudo-device works as a point-to-point connection, passing Ethernet frames over the Internet by encapsulating them inside UDP messages. The command line parameters specify the local UDP port number, and the IP address and UDP port number of the remote socket. This is mainly intended for attaching E11 machines to the HECnet (a worldwide hobbyist DECnet), through a remote machine running Johnny Billquist's "bridge" program. E11 will act as if there's a virtual Ethernet segment containing only a single PDP-11 and a PC running "bridge", with the bridge configured to link that segment to the specified remote system.

The virtual Ethernet port's default MAC address is always the same, which is fine if the PDP-11 is running DECnet and will immediately change the MAC address at startup to a new one based on the machine's DECnet address. Otherwise the address could conflict with other E11 machines, since "bridge" makes it seem as if they're all on the same physical Ethernet. In this case the default MAC address should be overridden using the `/MAC` switch, using a unique 6-octet value (unique on the linked LANs anyway) whose first byte has binary "10" in the low two bits (i.e. the second hex digit of the first pair is 2, 6, A, or E) to specify that it's a unicast address (as opposed to multicast) and it's locally administered (not part of a globally unique block assigned to a vendor by the IEEE).

7.2 Emulated PDP-11 network devices

This section describes each PDP-11 network device type emulated by Ersatz-11.

name	*units*	*controller*
NI*u*:	0–1	Interlan NI1010A, NI2010A Unibus/Q-bus Ethernet
XE*u*:	0–3	DELUA Unibus Ethernet
XH*u*:	0–1	DELQA Q-bus Ethernet

7.2.1 NI: — Interlan NI1010A, NI2010A Ethernet ports

The Interlan boards were early Ethernet interfaces, and have a simpler programming model than DEC's own Ethernet boards. Fuzzball and UNIX contain Interlan drivers. They were available in both Unibus (NI1010A) and Q-bus (NI2010A) versions, and the Q-bus version could be switched between 18- and 22-bit addressing. By default, E11 chooses the NI: device type based on the `SET CPU QBUS` setting.

`SET NI:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`DEFAULT`	set controller type to default (NI1010A for Unibus, NI2010A_Q22 for Q-bus)
`NI1010A`	set controller type to NI1010A
`NI2010A_Q18`	set controller type to NI2010A with Q18 addressing
`NI2010A_Q22`	set controller type to NI2010A with Q22 addressing
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

7.2.2 XE: — DELUA Ethernet port

The DELUA is a Unibus Ethernet board in a single hex-height module. It is a compatible upgrade to the DEUNA, which is made up of two hex-height modules and is slower and consumes more power. It is a sophisticated board which offloads a lot of processing from the PDP-11. The board contains its own echo server (for the ECT loopback protocol, 90-00) and generates system ID packets, both automatically (on a timer) and in response to requests from other nodes. It also maintains a "counters" page with transmit/receive statistics.

`SET XE:` controller parameters:	
`BOOT=`*ddcu*`:[/`*os*`]`	boot from specified device on reception of MOP boot packet
`BOOT=DISABLED`	disable remotely-initiated boot (default)
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`CSR=FLOATING`	set CSR address to be auto-configured
`DEUNA`	set controller type to DEUNA
`DELUA`	set controller type to DELUA (default)
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal
`VECTOR=FLOATING`	set vector address to be auto-configured

7.2.3 XH: — DELQA Ethernet port

The DELQA is a Q-bus Ethernet board in a single dual-height module. It is much simpler than the DELUA, and has a completely different programming model. It has a 4 KB boot/diagnostic ROM which can be copied into PDP-11 memory. The ROM contains a boot program which can downline load the PDP-11 over the network using the MOP load/dump protocol. D Bit's own MOP boot program is supplied in the "XHBOOT.BIN" file, which E11 locates using its usual search rules (see section 1.9). A `BOOT XH`*n:* command will cause this program to be downloaded from the emulated DELQA, and the PDP-11 operating system will be booted over the network, assuming a MOP load server is present which has the appropriate load images.

Note that the MOP load/dump protocol depends on using the Ethernet addresses of both the client and server machines, rather than a higher level media-independent protocol address, so it does not work through routers. The client and server must be on the same Ethernet segment.

`SET XH:` controller parameters:	
`BOOT=`*ddcu*`:[/`*os*`]`	boot from specified device on reception of MOP boot packet (DELQA only)
`BOOT=DISABLED`	disable remotely-initiated boot (default)
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`CSR=FLOATING`	set CSR address to be auto-configured
`DEQNA`	set controller type to DEQNA
`DELQA`	set controller type to DELQA (default)
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal
`VECTOR=FLOATING`	set vector address to be auto-configured

Chapter 8

DDCMP Network Links

The Digital Data Communications Message Protocol (DDCMP) was used extensively in DECnet LANs and WANs, especially in the days before Ethernet arrived and took over LANs. Although it can be implemented in software, it's normally handled by dedicated microprocessors, either in point-to-point links or with multidrop systems where a control station has multiple tributaries.

8.1 Emulated PDP-11 DDCMP network links

The available DDCMP device types are:

name	*units*	*controller*
`XD`*u*`:`	0–1	DMP11, DMV11 multidrop link
`XM`*u*`:`	0–1	DMR11, DMC11 point-to-point link

8.1.1 XD: — DMP11, DMV11 multidrop link

The DMP11 (M8207-YA hex Unibus SPC with M8203 universal line unit) and DMV11 (M8053 or M8064 quad Q-bus interfaces) are multidrop or point-to-point synchronous DDCMP links. The DMP11 is the same hardware as the DMR11 with different firmware, while the DMV11 is an entirely new implementation based on the 6510 microprocessor, on a single board with the modem built in.

8.1.2 XM: — DMR11, DMC11 point-to-point link

The DMR11 (M8207-RA hex Unibus SPC with M8203 universal line unit) and the earlier DMC11 (M8200 hex Unibus SPC with M8201 or M8202 line unit) are point-to-point synchronous DDCMP links which support local (hardwired) or remote (modem) connections at speeds up to 1 MBPS. The microcode is in ROM, which meant the DMC11 was never upgraded from the deprecated version of DDCMP (V3.03) that it uses. The DMC11 hardware architecture was almost immediately re-released as the KMC11, which is a general-purpose communications coprocessor whose microcode is loaded into RAM at runtime.

8.2 PC DDCMP drivers

Since DDCMP is carried over normal communications lines, E11 can support it by inserting a DDCMP layer between the emulated PDP-11 device and one of the usual communications devices. It can also layer the DDCMP protocol on top of TCP connections or UDP datagrams.

name	*type*	*switches*
`ASYNC:`	async serial line	none
`NULL:`	null device	`/NODE:`*area*`.`*node* `/POINTTOPOINT`
`SYNC:`	experimental sync serial line	none
`TCP:`	TCP connection	`/RETRY:`*n*
`UDP:`	UDP datagrams	`/CONTROL /POINTTOPOINT /TRIBUTARY:`*n*

8.2.1 ASYNC: — Asynchronous serial ports

Command syntax:

`ASSIGN` *ddu*`: ASYNC:` *pcdev*

Special switches: `/DSR:ON`

This layer works with any serial port supported by E11. It interoperates nicely with DECnet/RSX's async DDCMP implementation. The PDP-11 operating system may wait for DSR to come on before it's willing to use the port, so the `/DSR:ON` switch may be a handy workaround if your null-modem cable doesn't include all lines. Multidrop lines are not supported.

8.2.2 NULL: — Null device

Command syntax:

`ASSIGN` *ddu*`: NULL:`

Special switches: `/NODE:`*area*`.`*node* `/POINTTOPOINT`

This is a placeholder device, which allows a DDCMP port to be brought up with no hardware. `/NODE:`*area*`.`*node* makes the device pretend to have a (useless) neighbor at the specified DECnet address. `/POINTTOPOINT` is the default, and makes it a point-to-point line.

8.2.3 SYNC: — EXPERIMENTAL synchronous serial ports

Command syntax:

`ASSIGN` *ddu*`: SYNC:` *pcdev*

Special switches: `/DSR:ON`

This driver is not yet ready for use, but some users may be interested in experimenting with it. The only serial ports that E11 supports that have synchronous capabilities are the Sealevel Z8530/Z85230-based boards (`SCC:`).

They don't work yet. D Bit would be interested in working with anyone who wants to help with testing. Multidrop lines are not supported.

8.2.4 TCP: — TCP network connection

Command syntax:

`ASSIGN` *ddu*`: TCP:` *a*.*b*.*c*.*d*:*remport* [`/RETRY:`*n*] (client)
`ASSIGN` *ddu*`: TCP:` *interface*:*locport* `/SERVER` (server)
`ASSIGN` *ddu*`: TCP:` *locport* `/SERVER` (server is implied if no IP address)

This driver transfers DDCMP traffic over the Internet between cooperating emulated systems. Although TCP technically supports symmetric connections (both sides can try to initiate simultaneously and both will succeed), that requires each side to know the other's port number, and in practice most TCP-based protocols use a server with a port number that's known in advance, and a client that calls into that port, so that's how E11 does it. One system must be the client and the other must be the server. This has nothing to do with DDCMP, so the choice of which is which doesn't matter.

The client side uses the syntax in the first `ASSIGN` command above, to specify the remote IP address and port number that it will connect to. The `/RETRY:`*n* switch specifies the number of seconds between attempts in case the connection fails. The default is 30.

The server side may use either of the other two command formats. The `/SERVER` switch may be left off if there's no IP address given, since in that case E11 knows it has to be a server.

8.2.5 UDP: — UDP datagrams

Command syntax:

`ASSIGN` *ddu*`: UDP:` [*interface*:]*n* *a*.*b*.*c*.*d*:*remport* `/POINTTOPOINT` (point-to-point) (default)
`ASSIGN` *ddu*`: UDP:` [*interface*:]*n* `/CONTROL` (multidrop control station)
`ASSIGN` *ddu*`: UDP:` [*interface*:]*n* *a*.*b*.*c*.*d*:*remport* `/TRIBUTARY:`*n* (multidrop tributary station)

The UDP driver sends DDCMP messages as UDP datagrams. It has the advantages (over TCP) that there's no difference between clients and servers, there's no connection to keep alive, and because of those, multidrop is easy. E11's implementation of DDCMP over UDP currently cheats slightly and doesn't actually perform DDCMP polling. There's no need for it, since line-sharing is already done as needed by the UDP/IP/Ethernet protocols; any station may send a message whenever it wants.

The most common configuration (so it's the default) is a point-to-point connection, which is compatible with the DMR11. This version of the `ASSIGN` command gives the addresses of the local and remote ports. Each side gives its own port number (and optional interface name) first, and the other side's IP address and port number second.

For multidrop connections, one system is a control station for one or more tributaries. With real DDCMP these systems share one (wire-ORed) line and the control station determines whose turn it is to transmit. With UDP there's no need for that, but one system is still designated as the control station for the others. The `ASSIGN` command that sets up the control station doesn't give the destination address since there's more than one (i.e. one for each tributary). These are added after the port has been created, using a separate `SET` command for each

tributary:

`SET` *ddu*`: TRIBUTARY=`*n* `/DESTINATION:`*a*`.`*b*`.`*c*`.`*d*`:`*remport*

Tributaries each have an address, which is a number from 1 to 255 decimal. This number is specified in the `ASSIGN` ... `/TRIBUTARY:`*n* command which creates the tributary, and the same number must be used in the `SET` *ddu*`: TRIBUTARY=`*n* command which tells the control station how to find that tributary.

Chapter 9

Miscellaneous Devices

This chapter describes devices which don't fit into any of the major categories covered in the preceding chapters. This includes graphics displays, paper tape I/O, and the interface to the PC's native file system.

Miscellaneous PDP-11 devices:

name	*unit(s)*	*controller*	*command to create*	*type*
(none)			`LOAD/ROM`	ROM devices
`CD:`	0	CD11	`ASSIGN`	punched card reader
`CR:`	0	CR11, CM11	`ASSIGN`	punched card reader
`DO:`	0–3	virtual	`MOUNT`	PC file interface
`IX:`	A 0–1	IEU11A, IEQ11A	`ASSIGN`	dual GPIB ports
`KD:`	A	M8644 CDR	`ASSIGN`	countdown registers
`KG:`	0–1	virtual	`ASSIGN`	communications arithmetic board
`KP:`	0–1	KW11P	`ASSIGN`	programmable clock
`OA:`	0–3	DR11C/DRV11	`ASSIGN`	PIO digital I/O
`PP:`	0	PC11	`MOUNT`	paper tape punch
`PR:`	0	PC11	`MOUNT`	paper tape reader
`TK:`	0	Terak	`ASSIGN`	bitmapped graphics display
`VR:`	0	VT30	`ASSIGN`	color graphics display
`VT:`	0	VT11	`ASSIGN`	vector graphics processor
`XA:`	0–3	DR11W/DRV11WA	`ASSIGN`	DMA digital I/O
`XN:`	0–3	DN11	`ASSIGN`	auto-dialer

9.1 Installable user-written plug-in emulation modules

Command syntax:

`INSTALL` [*d*:*path*\]*filename*[`.DLL`]

Special switches: none

This command allows custom user-written (or third-party) plug-in emulation modules to be dynamically installed at run time. This makes it possible for custom hardware to be emulated, without requiring access to the Ersatz-11 source code. Modules are coded in C or 80x86 assembly language, and linked to produce Win32-format dynamic

link libraries (".DLL" files). The .DLL loader is part of E11 itself rather than a service of the PC operating system, so the same module format is used in the DOS, Windows, and Linux versions of Ersatz-11, allowing some modules to run unchanged in all environments.

E11 provides a wide selection of callable entry points to be used by the device emulation module. Typically a loaded module will uses these services to register a range (or ranges) of I/O page addresses which it wants to handle. Then, whenever the PDP-11 accesses a device register in that range, the user code is called to emulate the register. Calls are also provided to enqueue and cancel interrupt requests, and also to perform emulated DMA, allocate/free memory, etc. The programming interface is described in Appendix C.

Loadable modules can also provide a wide range of other services besides just emulating existing custom hardware. Modules have been written which support high-speed inter-task communications (to connect the PDP-11 system to other software running on the same PC under a multi-tasking operating system), extended memory for virtual arrays, and access to a dual-ported memory device for connecting to another processor, among other things.

D Bit can provide programming information, sample code, and consulting services for users who wish to implement a custom device emulation module.

9.2 ROM devices

Command syntax:

`LOAD/[EEP]ROM [/BANKED]` [*d*:*path*\]*filename*[*.PDP*] *start*[:*end*]
`LOAD/[EEP]ROM [/BANKED] NULL:` *start*[:*end*]

Special switches: `/BANKED`, `/EEPROM`, `/ROM`

E11 can simulate ROM devices, either simple unbanked ones such as the M9312 bootstrap/diagnostic board, or banked ones like the BDV11 board or the on-board ROM in the later quad-height Q-bus CPU modules.

ROM data are loaded from the specified binary file, which is located using E11's usual search rules (see section 1.9). Using `NULL:` as the filename reads all zeros, and can be handy for making place-holders for missing devices on the I/O page.

More than one ROM device can be loaded; for example, the individual 128-byte device bootstraps in a M9312 style ROM board (or the on-board equivalents in a PDP-11/24 or PDP-11/44 CPU) can be loaded from separate files with separate commands.

For linear (non-banked) ROMs, a starting address in the I/O page must be specified. The data from the file will appear starting at that address. If an ending address is specified, the file must be at least long enough to reach that address. If no ending address is given, the length of the emulated ROM is the same as the length of the binary file.

A M9312-style bootstrap/diagnostic ROM board can be configured and started with the following commands:

```
E11>LOAD/ROM DIAGBOOT.ROM 17765000
E11>LOAD/ROM RL02BOOT.ROM 17773000
E11>LOAD/ROM MSCPBOOT.ROM 17773200
...
E11>GO 165020
000000 000000 000000 000000
```

```
@
```

This is just an example of what can be done. Normally there would be no point in using the M9312 boot ROMs since E11 contains its own bootstraps for all bootable devices that it emulates. Anyway there may be legal problems with copying those ROMs into image files, since they are copyrighted by DEC.

For banked ROMs, the `/BANKED` switch must be used. The data from the file will appear through a 512.-byte window, and the page which is visible is selected by the PDP-11 using the page control register (PCR), which for emulation purposes is considered by E11 to be part of the CPU board (since in most cases, it is).

There are two styles of page control register. `SET CPU KDF11` (or `SET CPU BDV11`) selects the style used in the KDF11 on-board ROM (or the BDV11 boot/diagnostic board). `SET CPU KDJ11` selects the style used in the on-board ROM of the KDJ11x CPU boards.

The starting address for banked ROM windows is either (17)773000 or (17)765000. The windows must be 512. bytes long, which is E11's default anyway so there's no need to give the end of the address range. The `/EEPROM` switch means that the memory is actually EEPROM (as used on the KDJ11x CPU boards), and must go in the window starting at (17)765000. This is the default, so there's no need to give any address range at all with `LOAD/EEPROM`. Note that while the memory can be written, the data written are not saved to the file from which the EEPROM was loaded. Regular ROM data go in the window starting at (17)773000, so this is the default for `LOAD/ROM`.

ROM devices can be removed at any time using the `UNLOAD` command. The switches and defaults are the same as for `LOAD`, so the starting address of the ROM to remove need not be specified if the `/BANKED` switch is used.

9.3 CD: — CD11 punched card reader

Command syntax:

`ASSIGN CD`*cu*`:` [*d*:*path*\]*filename*[`.TXT`]
`ASSIGN CD`*cu*`:` [*d*:*path*\]*filename*[`.CRD`] `/BINARY`
`ASSIGN CD`*cu*`: NULL:`

Special switches: see below

The CD11 is a medium-speed (DMA) punched card reader. It reads a stack of 80-column, 12-row punched cards, which may contain binary data, or text encoded using various versions of Hollerith. The `ASSIGN CD:` command uses the same syntax as the CR11's `ASSIGN CR:` command, except for the device name itself. See below.

`SET CD:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`REWIND`	rewind card deck to beginning
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.4 CR: — CR11, CM11 punched card reader

Command syntax:

`ASSIGN CR`*cu*`:` [*d*:*path*\]*filename*[`.TXT`]
`ASSIGN CR`*cu*`:` [*d*:*path*\]*filename*[`.CRD`] `/BINARY`
`ASSIGN CR`*cu*`: NULL:`

Special switches: see below

The CR11 and CM11 are punched card readers. Ersatz-11 reads the card data from a PC file, which may be either in binary format (if `/BINARY` is specified), in which case each 12-bit column is right-justified in a 16-bit word stored in PDP-11 byte order, or plain ASCII text if `BINARY` is omitted. Text is punched on cards using one of several Hollerith codes, which PDP-11 device drivers normally translate to ASCII. The `/DEC026`, `/DEC029`, and `/IBM1401` switches specify which encoding the PDP-11 is expecting, so that E11 will do the inverse.

`ASSIGN CR: NULL:` gives a card reader that's always at the end of the deck.

`SET CR:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR6 for Unibus, BIRQ4 for Q-bus)
`REWIND`	rewind card deck to beginning
`VECTOR=`*nnn*	set vector address to *nnn* octal

The following `ASSIGN` switches apply to both `CD:` and `CR:`

`ASSIGN CD:/CR:` unit switches:	
`/026`	syn. for DEC026
`/029`	syn. for DEC029
`/1401`	syn. for IBM1401
`/ANSI`	syn. for DEC029 (it's really the ANSI variant)
`/BINARY`	binary file (otherwise ASCII)
`/DEC026`	use 029 keypunch code
`/DEC029`	use 026 keypunch code
`/DEC1401`	syn. for IBM1401
`/EOFCARD`	include virtual EOF card (default)
`/IBM1401`	use 1401 keypunch code
`/NOEOFCARD`	empty hopper when end of file reached
`/NOTABS`	disable tab expansion
`/TABS`	tabs every 8 columns (default)
`/TABS:`*n*	tabs every *n* columns
`/TABS:FORTRAN`	tabs using FORTRAN rules for columns 6/7

9.5 DO: — PC file access pseudo-device

Command syntax:

`MOUNT DO`*n*`:`

Special switches: none

DO: refers to the "DOS file device". This is a pseudo-device which allows privileged PDP-11 programs and/or device drivers to read and write native PC files from within the emulated PDP-11. It is compatible with the supplied DO.SYS device driver for RT-11, and the DOS.TSK program for RSX which is available from `ftp.dbit.com`. The

command to create a DOS file device is simply "MOUNT DO*n*:", since there is no particular physical PC device attached to the physical side of the emulation. In E11 prior to V2.2, one DOS file device was always configured, but now they must be created explicitly. Normally there's no reason to have more than one, so you can recreate the V2.1A behavior by simply adding "MOUNT DO:" to your E11.INI initialization command file.

9.6 IX: — IEU11A, IEQ11A dual GPIB interface

Command syntax:

`ASSIGN IX`*cu*`: NULL:`

Special switches: none

The IEU11A (M8648 hex Unibus SPC) and IEQ11A (M8634 quad Q-bus) boards are dual-channel GPIB ports. Ersatz-11's emulation of them is currently a partial proof-of-concept implementation, and works only with the `NULL:` device and the `LOG` command.

`SET IX:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`DEFAULT`	set controller type to default (IEU11A for Unibus, IEQ11A for Q-bus)
`IEU11A`	set controller type to IEU11A (Unibus)
`IEQ11A`	set controller type to IEQ11A (Q-bus)
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR6 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.7 KD: — M8644 countdown register board

Command syntax:

`ASSIGN KD`*c*`:`

Special switches: none

The M8644 countdown register board was a special-purpose device made by DEC Computer Special Systems. It countains four separate channels of 16-bit counters, each of which counts down every millisecond and can be configured to cause an interrupt upon reaching zero. The command to create a countdown register board is simply "ASSIGN KD*c*:", since there is no particular physical PC device attached to the physical side of the emulation. On the real device, the interrupt vector and priority were settable for each channel, so E11 has separate `SET` commands for each unit number, even though the four units are otherwise considered to be a single device.

`SET KD:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.8 KG: — KG11A communications arithmetic board

Command syntax:

`ASSIGN KG`*c*`:`

Special switches: none

The KG11A arithmetic option (M7251 quad Unibus SPC) is a simple coprocessor that helps with block checks used in communications, mainly CRCs. Since there's no PC device associated with it, the command to create a KG11A is just "ASSIGN KG*c*:". It does not use interrupts.

`SET KG:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal

9.9 KP: — KW11P programmable clock

Command syntax:

`ASSIGN KP`*n*`:` [*digital I/O device*]

Special switches: none

The KW11P (M7228) is a programmable clock, on a quad Unibus SPC. It has a 16-bit up/down counter which can be programmed for one-shot or periodic use. It has on-board crystal-controlled 10 kHz and 100 kHz clocks, and can also be triggered by the AC line frequency, which requires a connection from the power supply to pin CE1 of the KW11P's slot, or by low-to-high transitions on an external TTL input, which is connected to spade lugs on the M7228 board.

The usual command to create a KW11P is simply "ASSIGN KP*n*:", since there is no particular physical PC device attached to the physical side of the emulation. The 10 kHz and 100 kHz clocks are derived from the PC's internal timer, as is the AC line input, which ticks at the frequency set by the `SET HERTZ` command (60 Hz by default).

A digital I/O device name may optionally be given on the `ASSIGN KP:` command line. If it is, the device's first (or only) interrupt input is used as the KW11P's external clock input. Note that the PC device may not have a Schmitt trigger input like the real KW11P, and also that it may not count the same edge. The real KW11P counts on a low-to-high transition of the external input. A trivial circuit using one or two gates of a 74LS14 will solve these problems.

E11 includes a limited digital I/O driver for PC LPT ports, which is mainly useful with the KW11P emulation. A command like `ASSIGN KP: LPT1:` will create a KW11P clock which uses LPT1's $\overline{\texttt{ACK}}$ signal as its external clock input. This is a TTL input which appears on pin 10 of the LPT port's female DB25 connector. The ground leads are pins 18–25.

`SET KP:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR6 for Unibus, BIRQ6 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.10 OA: — DR11C, DRV11 digital I/O ports

Command syntax:

`ASSIGN OA`*n*`: ETHER:` *etherport* [*switches*]
`ASSIGN OA`*n*`: NULL:` [*switches*]

Special switches: `/INDELAY:`*n*, `/OUTDELAY:`*n*

The DR11C (M7860 quad Unibus SPC) and DRV11 (M7941 dual Q-bus card) are simple programmed I/O boards which provide unidirectional 16-bit input and output ports, two general-purpose control outputs, and two inputs which can be used for status and/or to generate interrupts. They do not use DMA, and are commonly used for connecting to simple external devices or for (relatively) low-speed inter-processor communications.

The `/INDELAY:`*n* and `/OUTDELAY:`*n* switches on the `ASSIGN` command may be used to slow down port access to accommodate slow external hardware. *n* is the number of microseconds to delay before reading the input lines, or after writing the output lines. These may also be used as `INDELAY=`*n* and `OUTDELAY=`*n* options on a `SET OA:` command line.

`SET OA:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`INDELAY=`*n*	set delay before reading in usec (0–1000)
`OUTDELAY=`*n*	set delay after writing in usec (0–1000)
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal
`VECTOR=FLOATING`	set vector address to be auto-configured

9.10.1 ETHER: — Point-to-point IPL using Ethernet

See discussion under DR11W (`XA:`).

9.10.2 NULL: — Null device

See discussion under DR11W (`XA:`).

9.11 PP: — PC04 paper tape punch

Command syntax:

`MOUNT PP:` [*d*:*path*\]*filename*[`.PAP`]

Special switches: none

The PC04 is a high speed paper tape reader/punch, interfaced to the PDP-11 through a PC11 interface. This command attaches the specified PC file to the output half of the device, so that data bytes sent to the punch will be written to the file instead.

In E11 prior to V3.0, one paper tape reader/punch was always configured, but now they must be created explicitly. You can recreate the V2.2 behavior by adding "`MOUNT PR: NULL:`" to your E11.INI initialization command file, and issue new MOUNT command(s) later to change the file(s) used.

See below for `SET` commands. The PC11 is a combined reader/punch controller so one set of settings configures both the reader and punch halves.

9.12 PR: — PC04 paper tape reader

Command syntax:

`MOUNT PR:` [*d*:*path*\]*filename*[`.PAP`]
`MOUNT PR: NULL:`

Special switches: none

This command attaches the specified PC file (or a host-OS-independent null device) to the input half of the PC11/PC04, so that input bytes will come from the file. The `BOOT PR:` command supports binary executable tape images written in the Absolute Loader format (e.g. by the `LINK /LDA` command in RT-11). The `SET PR: REWIND` command will reset the tape to begin reading at the beginning of the file on the next access.

In E11 prior to V3.0, one paper tape reader/punch was always configured, but now they must be created explicitly. You can recreate the V2.2 behavior by adding "`MOUNT PR: NULL:`" to your E11.INI initialization command file, and issue new MOUNT command(s) later to change the file(s) used.

`SET PR:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`REWIND`	rewind tape to beginning
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.13 TK: — Terak bitmapped graphics display

Command syntax:

`ASSIGN TK: CON`*n*`:`

Special switches: none

The Terak 8510/a's most notable feature is a bitmapped 320x240 graphics display, superimposed on an 80x24 text display (640x240 pixels) with the character generator in RAM. See Appendix E for a sample initialization file for emulating a Terak system.

The graphics display also includes hardware to emulate the standard 177560/60 console DLV11 port. The "receive" half of the port is real, and is connected to the Terak keyboard. The "transmit" half is designed to work with a software terminal emulator. If a character is written to the transmit buffer register (at 177566), an interrupt (normally to vector 164) happens immediately. The interrupt service routine reads the character back out of the

transmit buffer, at which point the port signals completion the same way a DLV11 does (by setting the "ready" bit in the transmit CSR at 177564, and interrupting through vector 64 if interrupts are enabled). Meanwhile the interrupt service routine (for vector 164) takes care of updating the screen.

Since the DLV11-like port uses the same addresses as TT0: (E11's console terminal), a "SET TT0: CSR=nnnnnn" command should be issued to move TT0: to a non-conflicting address before ASSIGNing TK:. TK:'s CSR/VECTOR settings are for the DLV11-like console port. The CCSR address is for the 4 KB character memory window (switchable between the page buffer and the character generator with a CSR bit), and the GCSR address is for the graphics controller's three registers.

`SET TK:` controller parameters:	
`CCSR=`*nnnnnn*	set character buffer CSR address to *nnnnnn* octal
`CSR=`*nnnnnn*	set DLV11 CSR address to *nnnnnn* octal
`EVECTOR=`*nnn*	set terminal emulator vector address to *nnn* octal
`GCSR=`*nnnnnn*	set graphics controller CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.14 VR: — VT30 color graphics display processor

Command syntax:

`ASSIGN VR: CON`*n*`:`

Special switches: none

The VT30 "Colour Mimic Diagram Display System" is a simple display-list-based raster graphics device, built by DEC CSS in Reading, UK. It is a Unibus device, mounted in a 5.25" high external box. It displays 8x8 characters from a software character generator on a 64x36 grid, yielding 512x288 pixels, displayed on an attached PAL monitor.

E11 requires an EGA, VGA, or SVGA with at least 256 KB of memory to emulate the VT30. The VT30 screen can be popped up with an Alt-function key just like a VT100 session.

`SET VR:` controller parameters:	
`COLOR`	color monitor (default)
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`GRAYSCALE`	gray-scale monitor (for future expansion, currently always white)
`MONOCHROME`	monochrome monitor (black or white only)
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.15 VT: — VT11 vector graphics display processor

Command syntax:

`ASSIGN VT: CON`*n*`:`

Special switches: none

The VT11 vector graphics display processor consists of three hex-height boards in a 4-slot backplane. It maintains the picture on a VR14 or VR17 monitor by constantly scanning a display list held in PDP-11 memory, and refreshing each vector many times per second. It can be used with a DEC model 375 light pen, and an LK40 ASCII keyboard.

In order to emulate a VT11, E11 requires a Super VGA graphics card with a VESA BIOS and at least 1 MB of video memory. The VT11 is assigned to one of the twelve possible virtual console sessions, so it can be popped up with an Alt-function key just like an emulated VT100 session, except of course that it runs the display in graphics mode.

If a mouse is present, it is used to emulate the DEC model 375 light pen. The crosshairs indicate the mouse position continuously (since a mouse can't be lifted away from the screen like a real light pen), so the left mouse button is used to indicate whether a light pen "hit" should be allowed to register. The PC keyboard takes the place of the LK40 keyboard on a GT40 system, so all keyboard input typed to a VT11 session is sent to TT0:.

`SET VT:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal

9.16 XA: — DR11W, DR11B, DRV11WA, DRV11B digital I/O ports

Command syntax:

`ASSIGN XA`*n*`: ETHER:` *etherport* [*switches*]
`ASSIGN XA`*n*`: NULL:` [*switches*]

Special switches: `/DIRECTION:`*xxxxxxxx*

The DR11W, DR11B, DRV11WA, and DRV11B are DMA I/O boards which provide 16-bit input and output ports, which transfer data in and out of PDP-11 memory using DMA. They look more or less like a typical disk/tape controller to software, with the usual registers for the bus address and word count, and a CSR with three function bits and a "GO" bit. There are also three status bits which are controlled by the attached device, and an "attention" mechanism for notifying the PDP-11 of asynchronous events. They are typically used to connect high-speed external devices, or for high-speed inter-processor communications.

The DEC DR11W (etc.) interface cables have a pin called C1 CNTL H (or some variant) which tells the DR11W whether to transfer data from memory to the external device, or the other way around. PC digital I/O devices typically aren't able to choose the direction on the fly like this, and are designed to be programmed for the proper direction before the block transfer begins. Since the real DR11W doesn't work this way, the PDP-11 program doesn't set the direction into the interface, and anyway there's no register bit to indicate it.

This means that Ersatz-11 has no way of knowing the direction of transfer, so it can't program the PC interface with the proper direction. To work around this, `ASSIGN XA:` takes the "`/DIRECTION:`*xxxxxxxx*" switch. This method assumes that for each possible combination of the three FNCT bits on the interface (which are written by bits 1-3 of the DR11W CSR), the direction of transfer is always the same. The *xxxxxxxx* string contains one letter for each possible function opcode 0–7. The letter is "`I`" if that opcode indicates an input transfer from the external device to the PDP-11, or "`O`" if the opcode means DMA output from the PDP-11 to the device. For function codes that are never used, the setting does not matter. It may take some experimentation and/or test equipment to determine the correct directions, if the DR11W driver source code is not available, since unfortunately there's no way for E11

to auto-detect this.

SET XA: controller parameters:	
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
CSR=FLOATING	set CSR address to be auto-configured
DR11B	set controller type to DR11B
DR11W	set controller type to DR11W
DR11W_NOEIR	set controller type to DR11W with error/information register disabled
DRV11B	set controller type to DRV11B
DRV11WA	set controller type to DRV11WA
DRV11WA_Q18	set controller type to DRV11WA with Q22 bus address extension register disabled
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR5 for Unibus, BIRQ4 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal
VECTOR=FLOATING	set vector address to be auto-configured

9.16.1 ETHER: — Point-to-point IPL using Ethernet

Command syntax:

ASSIGN XA*n*: ETHER: *etherdev* [*switches*]

Special switches: none

This interface is provided for using a pair of emulated DR11Ws as a point-to-point inter-processor link between E11 systems. It uses a simple private protocol (details available upon request) using DEC's "customer" protocol number, so it should not interfere with most Ethernet traffic, but it's really intended for point-to-point connections (two NICs cabled directly together with no hub) and uses the broadcast address, at least until it discovers the other side's MAC address.

9.16.2 NULL: — Null device

Command syntax:

ASSIGN XA*n*: NULL: [*switches*]

Special switches: none

Placeholder device. Ignores output, and all lines read as zeros.

9.17 XN: — DN11 auto-dialer controller

Command syntax:

ASSIGN XN*n*: *pdp11dev*: [*switches*]

Special switches: /DIRECTORY:[*d*:*path*\]*filename*[.TXT]

The DN11 is a controller for the Bell 801 automatic calling unit (ACU), which is a touch-tone dialer that's typically paired with a Bell 212A modem (etc.). It transmits digits and receives status using a simple parallel interface with RS232-like signal levels. A DN11AA backplane accepts up to four DN11AD units, each of which drives its own 801 while sharing selection/interrupt hardware with the other units in the backplane.

The `ASSIGN` command specifies which PDP-11 device is dialed by this DN11 unit. This is meaningful only for serial and DDCMP devices, and only if they're connected to PC devices that can make outgoing connections. For serial lines this means any real serial port that has the `HAYES:` layer in front of it. The DN11 will dial the real modem in this case. The `TELCLIENT:` device can also be dialed by a DN11. For DDCMP network devices, the DN11 works with real asynchronous/synchronous ports (which again must be behind a `HAYES:` layer), or with `UDP:` or `TCP:` connections. If the DN11 is connected to a PDP-11 device which can't usefully dial out, dialing has no effect.

The `/DIRECTORY` switch gives the name of a text file which translates between the telephone number sent to the DN11 and the actual telephone number or network address to used. Each line of the file has the telephone number to replace, an equals sign, and the string to use as a substitute, for making the actual connection. Blanks are ignored, as are `(`, `)`, `-`, and `.` characters in the phone number, and everything after a `;` or `!` is a comment. Whatever's to the right of the equals sign is used for making the connection. For `HAYES:` this is just another telephone number, but it can include things like "`,`" (which adds a delay in the ATDT command) which can't be sent by a DN11. For network connections, it's the remote network address, of the form "*a.b.c.d*`:`*port*".

Sample directory file:

```
; dialed = actual
(800) 258-1710 = 192.168.1.99:1134
547-4005 = 10.1.0.6:23
411 = 127.0.0.1:32767
```

`SET XN:` controller parameters:	
`CSR=`*nnnnnn*	set CSR address to *nnnnnn* octal
`PRIORITY=`*n*	set interrupt priority to *n* (4–7)
`PRIORITY=DEFAULT`	set interrupt priority to default (BR4 for Unibus, BIRQ4 for Q-bus)
`VECTOR=`*nnn*	set vector address to *nnn* octal
`VECTOR=FLOATING`	set vector address to be auto-configured

Chapter 10

Commands

Ersatz-11 recognizes many keyboard commands. These are entered at the "E11>" prompt, which appears whenever the PDP-11 is halted (e.g. at startup) but may be brought up at any time by pressing Shift-Enter or Alt-SysReq, or by pressing the BREAK key on a serial terminal if the console terminal (TT0:) has been ASSIGNed to a COM port. The SET BREAK command can define a regular ASCII character that pops up a prompt if these methods are all inconvenient. Some versions of the Windows DOS box intercept Alt-SysReq, but Shift-Enter still works. Commands (and parameters and switches) may generally be shortened to any unique abbreviation. Note that E11 is multithreaded and PDP-11 code continues to be executed while you are entering commands at the prompt, if you haven't HALTed it.

Ersatz-11 supports command line editing and recall at the "E11>" prompt, using the VT52/VT100 arrow keys and some control characters.

key	*action*
CTRL/A	go to beginning of line
CTRL/D	delete character to right of cursor
CTRL/E	go to end of line
CTRL/H	go to beginning of line
CTRL/J	delete word to left of cursor
CTRL/K	delete to end of line
CTRL/L	clear screen and re-display line
CTRL/R	re-type line
CTRL/U	delete to beginning of line
CTRL/W	delete word to left of cursor
CTRL/Z	exit prompt and connect to TT0:
DEL	delete character to left of cursor
left arrow	move left one character
right arrow	move right one character
up arrow	move up a line in history buffer
down arrow	move down a line in history buffer

@*file*[.CMD]

Accepts input from the specified file as if it had been typed at the E11 prompt. The default extension is ".CMD", and search rules are the same as for the E11.INI initialization file (see section 1.9). Command files may be nested up to four deep. Lines read from the file are not echoed.

ADDPCI *type parameters*

Adds non-standards-compliant PCI devices to E11ś internal tables so that they may be used in future ASSIGN commands. This command should normally never be needed, but it can be useful in cases where a PCI device is actually part of a standard class but reports itself as some other class, for example if it's part of a multi-I/O card. Each ADDPCI command searches the PCI bus for devices which fit the search criteria, and adds them to the end of the COM: or LPT: tables as they are found. So if E11 has already found COM1: through COM3: at startup and the ADDPCI command is used to find another 16550A-style serial port, it will be COM4:.

The *type* must be either COM: or LPT:, and specifies which type of device E11 should assume it has found. The parameters can consist of any mixture of search terms (at least one is required) and base address specifications (if none is specified, all six PCI base address registers will be used if they exist on this device).

The search terms are listed below. Any that is not specified is wildcarded.

- BUSDEVFN=*bb-dd-f* (PCI bus/device/function, each field is a hex number or * for wildcard)
- CLASS=*xxxxxx* (24-bit PCI class number in hex)
- DEVICEID=*xxxx* (16-bit device ID)
- VENDORID=*xxxx* (16-bit PCI vendor ID)
- SUBDEVICEID=*xxxx* (16-bit sub device ID)
- SUBVENDORID=*xxxx* (16-bit sub vendor ID)

Each PCI device has a configuration header which contains six base address registers, any or all of which can describe a block of port addresses used by that device. Very often only one base address register is active so there's no question where to find the port(s), but sometimes the block is larger than the number of working ports it contains, or there are two different types of devices in the same block, or there are multiple blocks and not all of them contain standard ports (there may be a PCI interface chip visible in one of the blocks).

If ADDPCI should assume that all base address registers contain nothing but valid ports of the type it's looking for, there's no need to include any base address specifications. Otherwise one or more blocks of valid ports may be described with (a) specification(s) of the form "BAR*a*[+*b*][=*c*]". *a* says which of the six base address registers to check, 0–5. *b* (if specified) is the hex offset from the start of the base address where the generic port(s) start(s) (default is 0, ports start at the beginning of the block. And *c* is the number of generic port(s) found at that address (the default is however many fit into the rest of the block).

If the command succeeds in finding new ports, they will be immediately visible using SHOW COM: or SHOW LPT:, and may be used in ASSIGN commands.

Example:

```
ADDPCI COM: VENDORID=8086 DEVICEID=9999 BAR1=4
```

This looks for PCI devices with the specified PCI vendor and device IDs, and assumes that each board found contains four 16550A-style COM: ports in its BAR1 address block.

`ASSEMBLE` [*/switches*] [*addr*]

Starts the mini-assembler at the specified address, in the specified address space (syntax and defaults are the same as for the `LIST` command). E11 will prompt with the address, and you can type in lines of PDP-11 assembly code, which E11 will translate to machine language and deposit into PDP-11 memory at that address. E11 keeps prompting for more lines (at updated addresses) until the user enters a blank line, or types CTRL/C. The syntax is a subset of the standard MACRO-11 syntax. Simple expressions are allowed in operands but there is no symbol table, macro processor, or conditional assembly. Only the .BYTE, .WORD, .BLKB, .BLKW, .ASCII, and .ASCIZ pseudo-operations are supported.

Example:

```
E11>a 1000
001000  mov     #1022,r5        ;point at string
001004  tstb    @#177564        ;is port ready?
001010  bpl     1004            ;spin until it is
001012  movb    (r5)+,@#177566  ;send next character
001016  bne     1004            ;loop unless it was a NUL
001020  halt                    ;stop in that case
001022  .asciz  /Hello there/<15><12> ;test string
001040  ^C
E11>g 1000

Hello there

%HALT
R0/000000 R1/000000 R2/000000 R3/000000  CM=K PM=K PRIO=0
R4/000000 R5/001040 SP/000000 PC/001022  N=0 Z=1 V=0 C=0
001022  add     (r5)+,(r0)
E11>
```

`ASSIGN` *pdp11dev*: *pcdev*: [*switches*]

Assigns a physical PC device to emulate the specified PDP-11 serial or network device. See chapter 6 for information about serial devices, and chapter 7 for information about network devices.

pdp11dev is the name of the PDP-11 device name being created. It conforms to the syntax defined in section 1.8. The first two letters define the device type, and are generally the same as the PDP-11 operating system's name for that device.

pcdev is the name of the PC device which will emulate this PDP-11 device. Within each class of peripherals (serial, network), any PC device may be used to emulate any similar PDP-11 device.

The optional *switches* consist of keywords which begin with a forward slash character ("`/`"). Some switches take a value, which is preceded by a "`:`" or "`=`" character. The acceptable switches vary depending on the device names used. See the section describing the device for more information.

Most `ASSIGN` commands can accept a range of unit numbers in the *pdp11dev* device name, and will create every unit in the range with one command. This is done by giving the device name with the lowest unit number first, followed immediately by a hyphen, and then the highest unit number. For example, "`TT1-4:`" refers to `TT1:`, `TT2:`, `TT3:`, and `TT4:`. *pcdev* should not contain a range. It should refer to the unit that goes with the lowest PDP-11 unit number. This unit number is incremented automatically for the other devices in the range, except for cases like "`TELNET:`" and "`NULL:`" where this wouldn't make sense.

`BOOT` *ddu*`:` [`/`*switches*]

Boots the system from the specified disk, magnetic tape, DECtape, network device, or paper tape. The disk/tape must have been mounted with the `MOUNT` command, unless it is a real device attached through a bus adapter. The optional switch is an OS name. Useful switches are `/RT11` and `/RSTS`. `/RSX` is accepted too but has no special effect. This has to do with the method used to pass time and date information to a newly booted monitor. RT-11 ignores the time and date passed at 005000 unless the NOP in word 000000 of the bootstrap is cleared to 0 (HALT) and the bootstrap is entered at 000002. RSTS uses the time and date at 001000 (in a different format from RT-11) regardless of whether its NOP was cleared, but later versions of RSTS save the first word of the bootstrap and execute it later, so they will halt if the system was booted the RT-11 way. Hence Note that the OS switches are meaningful only on block devices. If you prefer to set the time and date manually then the switch is not needed. RSX doesn't have a way to pass the time and date to a fresh monitor, so you'll have to use "F12" with a TIM command, or else use the TOY.TSK program (available on ftp.dbit.com) to read the TOY clock, which can be enabled on any emulated CPU type by putting `ASR` as the last item on the SET CPU command line. Recent RSX-11M-PLUS versions have a built in `TIM /SYN` command to do this, which works if the CPU type is PDP-11/93 or PDP-11/94.

There is also a `/HALT` switch, which tells E11 to go as far as loading block 0 into core and setting up the registers, but to stop there. This can be handy for debugging boot blocks.

The `BOOT PR:` command expects a tape image in absolute binary format, as produced by the "`LINK /LDA`" command under RT-11.

`CALCULATE` *expr*
`&` *expr* (synonym)

Calculates the value of a 32-bit expression and displays the result in octal, decimal, hex, ASCII and radix-50. The operators are `* / + -`, unary `+ - ^C` (where "^C" means logical complement), and `( )`, with the usual precedence. `&` and `!` are the bitwise AND and OR operators, and have the same precedence as `*` and `+`, respectively. Numbers are either octal digit strings, or decimal if they contain `8` or `9` or end in "`.`", or hex if preceded by "`^X`", or radix-50 triplets if preceded by "`^R`". General register contents may be specified using the names `R0`–`R5` (with a "`'`" suffix to indicate the other register set, when emulating a PDP-11 with dual register sets) or `SP` or `PC`, `R$` or `PS` means the processor status word, and something of the form "`'a`" means the ASCII value of the character "`a`".

E11 can accept expressions in most of the commands or switches which take numeric arguments. The default radix depends on the particular command or switch.

`C:` (etc.)

Changes the default PC disk drive to the one specified.

`CD` [*d*`:`][*path*]

Changes the current directory on the PC, or displays the current directory if none is given.

`DEFINE KEYPRESS` *keyname* `=` *statement*
`DEFINE KEYRELEASE` *keyname* `=` *statement*
`DEFINE MOUSEPRESS` *buttonname* `=` *statement*
`DEFINE MOUSERELEASE` *buttonname* `=` *statement*

Defines the action taken when the specified key or mouse button is pressed or released. Keyboard operation is defined using a simple script language, which allows the user to bind a small script to any possible keypress or keyrelease, which is executed whenever that key is pressed (`DEFINE KEYPRESS`) or released (`DEFINE KEYRELEASE`). The mouse uses the same keyscript language, defined using the `DEFINE MOUSEPRESS/MOUSERELEASE` commands.

When E11 is first started, the keyboard is initialized with a set of scripts which define the action of a VT100-like keyboard with a US English layout. Just like user definitions, these default scripts may be displayed with the SHOW KEYPRESS (MOUSEPRESS) and SHOW KEYRELEASE (MOUSERELEASE) commands. By default most keys do nothing on release and have no KEYRELEASE definition, except for the Alt, Ctrl, and Shift keys, and the left mouse button. Using the "E11.INI" initialization file, the user may easily redefine some or all of the keyboard and/or mouse as required. The keyscript language is described in Appendix A, and the list of key names that E11 accepts is in section A.3.

DEFINE LED *ledname* = *flag*

Defines which flag is tracked by each keyboard LED. LED names are CAPS, NUM, and SCROLL. The flag may be the name of any flag (read-only or read/write) from the keyboard script language, in which case the LED turns on when the flag is set and turns off when the flag is clear. Or it may be NONE to turn the LED off permanently. Flag names and meanings are described in section A.4.

DEASSIGN *ddu*:

Disables the specified character or network device. Deassigning TT0: is not allowed (either explicitly, or implicitly by ASSIGNing its PC device to another PDP-11 device). Unit-number ranges are accepted, to remove multiple devices with one command.

DEPOSIT [*/switches*] *addr* val_1 val_2 ...

Deposits the word(s) val_1, val_2 etc. starting at memory address "*addr*," which is forced even. An error message is returned if an attempt is made to access a nonexistent CSR in the I/O page (bus timeout). The address space to use is specified by the switch(es), or the space used in the last EXAMINE or DEPOSIT command is used by default if none are given. See the EXAMINE command for a list of valid switches.

DIRECTORY [*d:*][*path*][*wildcard*]

Displays a list of PC files that match the specified wildcard. The listing pauses at the end of each screen. Typing "Q" (or CTRL/C) ends the listing, carriage return advances by one line, and any other character advances to the next screen.

DISMOUNT *ddcu*:

Dismounts the specified mass storage device (see MOUNT). Unit-number ranges are accepted, to remove multiple devices with one command.

DUMP [*/switches*] [*d:path\]filename*[.PDP] [s_1:e_1 s_2:e_2 ... s_n[:[e_n]]]

With no switches, dumps PDP-11 memory to the specified PC file (default extension is ".PDP"). Any number of address ranges "s_i:e_i" may be given, and data will be dumped to the file from each range in the order given in the command line. The last range may have no ending address, in which case file data are dumped until the end of memory. If no ranges are given at all the default is to dump all of PDP-11 memory starting at 000000.

With either the "/ROM" or "/EEPROM" switch, dumps a range of ROM or EEPROM to the file. The ROM/EEPROM must have been created with "LOAD/ROM" or "LOAD/EEPROM". Only one address range may be specified. It must begin at the beginning of the ROM but may end before the end of the ROM. The "/BANKED" switch can dump all of a banked ROM if only the starting address is given (rather than dumping only up to the first 512. bytes), in this case the starting address can be omitted too, (17)773000 is the default for "/ROM" and (17)765000 is the default for "/EEPROM". If no ending address is given, the default is to dump out the whole ROM.

EDIT *filename*

Starts the text editor, for editing files on the host operating system. The keypad commands are a greatly simplified subset of KED, or of EDT's "change" mode, so you probably already know how to use them. Press PF2 (normally mapped to the keypad's `/` key) for the "help" screen, which shows what the keypad keys do. CTRL/Z (or GOLD-7) will bring up a command prompt, which accepts command-line-oriented commands. The most important ones are `EXIT` (save file and exit) and `QUIT` (abandon edits and exit). It's a fairly bare-bones command set, except for a few special-purpose commands that might be useful to someone who, for example, is writing a PDP-11 emulator in 80x86 assembly language.

Highlights of editor commands:

- Keypad: similar to KED or EDT.
- `LOCALS`: similar to KED, but uses a select range.
- `FILL '`*prefix*`'`: same as `FILL` with no argument, but preserves a prefix string on each line (or adds it if missing). Useful for rejustifying comment blocks in some programming languages (e.g. "`FILL /; /`").
- `INSERT` *filename*: insert a file.
- `WRITE` *filename*: write the select range to a file.
- `APPEND` *filename*: append the select range to a file.
- `SET EOL CRLF`: uses CR/LF as the end-of-line sequence. Synonym: `SET EOL DOS`.
- `SET EOL LF`: uses LF alone as the end-of-line character. Synonym: `SET EOL UNIX`. Default is auto-detected from the file read, or from the host OS if creating a new file.
- `SET` [`SOFT`]`TABS` *parm*: set tab stops etc. for both hard tabs (using the ASCII TAB character) and soft tabs (which are done using spaces alone). Values for *parm*:
  - `OFF`: disable [soft] tabs entirely.
  - `ON`: enable [soft] tabs according to last settings used.
  - *a b c ...*: set tab stops at the specified columns (1 = left margin).
  - `EVERY` *n*: set tab stops every *n* columns.
- `SET CONTROL` *parm*: set how control characters are displayed:
  - `LETTER`: circumflex and a letter, e.g. `^C` for 003.
  - `SYMBOLIC`: (default) symbolic name, e.g. <`ETX`> for 003.
- `ESC o`: check to see if the symbol under the cursor is the only occurence of that symbol name in the file.
- `ESC r`: change the radix of the numeric constant under the cursor, using MASM syntax. Suffixes (also used in response to prompts for old/new radix) are 'b', 'o' or 'q', 'd', or 'h' for binary, octal, decimal, or hex.

`EXAMINE` [*/switches*] [*addr* [*end*]]

Examines the word at memory address *addr*, which is forced even. If *end* is specified then a range of words is displayed. If both are missing then the 8 words following the last location accessed with `EXAMINE` or `DEPOSIT` are displayed. An error message is returned if an attempt is made to access a nonexistent CSR in the I/O page (bus timeout). The address space to use is specified by the switch(es), or the space used in the last `EXAMINE` or `DEPOSIT` or `MAP` command is used by default if none are given.

Switches:

switch	*space*
`/CURRENT`	Current CPU mode, specified by $PSW_{15:14}$
`/PREVIOUS`	Previous CPU mode, specified by $PSW_{13:12}$
`/KERNEL`	Kernel mode
`/SUPERVISOR`	Supervisor mode
`/USER`	User mode
`/INSTRUCTIONS`	I space (within one of the above modes)
`/DATA`	D space (within one of the above modes)
`/PHYSICAL`	Physical 22-bit address space (default if MMU disabled)

Note that the address space switch(es), if any, must be given before the address expression on the command line, to avoid ambiguity since the switch character ("`/`") is used for division in expressions.

`FPREGISTER` [r v_1 v_2 [v_3 v_4]]

Sets or displays the FPP registers. r is the FP accumulator number, `0`–`5`, and v_1–v_4 are two or four 16-bit octal words to write in the register (sorry, not decimal). If no arguments are given then the octal contents of all six ACs are given, along with octal displays of the `FPS`, `FEC`, and `FEA`, and also a bit-by-bit display of `FPS`.

`GO` [*addr*]

Starts the machine at the specified address, or at the address currently in the program counter if none is given.

`HALT`

If the machine is running, halts it and displays the registers. Otherwise a no op.

`HELP` [*command*]

Explains use of Ersatz-11 commands. Just type "`HELP`" for a list.

`INITIALIZE`

Initializes all emulated I/O devices, disables the MMU, sets the CPU mode to "kernel."

`KERMIT`

Brings up a Kermit client, for performing file transfers over the virtual serial line between the console terminal and the emulated PDP-11, as if the console were a free-standing terminal program on the PC. The client should be generally familiar to anyone who's used a typical Kermit program. It's somewhat bare-bones in terms of command-line features, but the protocol implementation is thorough and includes sliding windows and long packets. Kermit may be useful as a last-ditch method of file transfer, for systems where direct insertion/extraction of files into/from the disk image(s) is not practical, and no driver is available for the host file access device (DO:).

`CD` *dir*	(or `CWD`) Change PC directory.
`CONNECT`	(or blank line) Connect to PDP-11 in pass-through mode.
`FINISH`	Shut down Kermit server on PDP-11.
`GET` *filespec* [*pcfilespec*]	Receive file(s) from PDP-11 (with optional renaming).
`HELP` [*command*]	Display help information on Kermit commands.
`RECEIVE` [*pcfile*]	Receive (and optionally rename) file from PDP-11.
`REMOTE CD` *dir*	(or `CWD`) Change PDP-11 directory.

REMOTE DIRECTORY [*filespec*]	Display a directory of PDP-11 files.
REMOTE KERMIT *cmd*	Execute arbitrary command on server.
REMOTE SET FILE TYPE BINARY	Sets both client and server to transfer files in raw mode (all bytes unchanged).
REMOTE SET FILE TYPE TEXT	Sets both client and server to transfer files in text mode (line endings/lengths may be converted as needed).
REMOTE SPACE [*filespec*]	Show disk allocation.
SEND *pcfile* [*pdp11file*]	Send (and optionally rename) file(s) to PDP-11. If *pcfile* is a wildcard, *pdp11file* replaces only the first matching name; other wildcard matches are sent with their real names.
LOGOUT	(or BYE) Shut down Kermit server on PDP-11 and log out.
QUIT	(or EXIT) End use of Kermit client.
SET BLOCK-CHECK *n*	Set block check type to 1, 2, or 3 (meaning a 1- or 2-byte additive checksum, or a 3-byte CRC).
SET FILE NAMES CONVERTED	Transmitted filenames will be normalized to remove possibly controversial characters.
SET FILE NAMES LITERAL	Transmitted filenames will be in native format of host PC OS.
SET FILE TYPE BINARY	Set client to transfer files in binary mode (you probably also want REM K SET FILE TYPE BINARY, unless the server is new enough to understand REM SET FILE TYPE BINARY, which sets both the client and server at once).
SET FILE TYPE TEXT	Set client to transfer files in text mode (also use REM SET FILE TYPE TEXT or REM K SET FILE TYPE TEXT).
SET TRANSMIT PAUSE *n*	Add an *n*-millisecond delay after each CR character sent with the TRANSMIT command. This will likely be needed to prevent overruns, since TRANSMIT doesn't use flow control.
TRANSMIT *pcfile*	Send text file directly, with no Kermit protocol. SET TRANSMIT PAUSE *n* may be used to add an *n*-millisecond delay after each CR character sent.

LIST [*/switches*] [*addr*]

Disassembles eight instructions starting at the specified address if it is given, or otherwise at the first address following the last one disassembled by the most recent LIST or REGISTER command. The address space to use is specified by the switch(es), or the space from the last LIST command is used if none are given. The default for LIST is set to /CURRENT /INSTRUCTIONS after each register dump, either from a REGISTER command or from the register display from a STEP command or CPU halt. See the EXAMINE command for a list of valid switches.

LOAD [*/switches*] [*d*:*path*\]*filename*[.PDP] [s_1:e_1 s_2:e_2 ... s_n[:[e_n]]]

With no switches, loads the specified PC file into PDP-11 memory (default extension is ".PDP"). Any number of address ranges "s_i:e_i" may be given, and data from the file will be loaded into each range in the order given in the command line. The last range may have no ending address, in which case file data are loaded until end of file is reached. If no ranges are given at all the default is to load the file at 000000. This command may be useful with binary files produced by Strobe Data Inc.'s PDPXASM cross-assembler.

With either the "/ROM" or "/EEPROM" switch, creates a ROM/EEPROM page and loads its contents from the file. The ROM contains a linear copy of the file contents, unless the "/BANKED" switch is also given, in which case it is banked through a 512.-byte window at either (17)773000 or (17)765000, using the page control register (see the "PCR" option under SET CPU). Only one address range may be given. If "/BANKED" switch is specified, the address range must be exactly 512. bytes long and must begin at one of the addresses given above. If "/EEPROM" is specified, the starting address must be (17)765000, so this address will be used by default, otherwise (17)773000

is the default. Otherwise, if only the starting address is given, the size of the ROM depends on the size of the file. If an ending address is given, the file must be large enough to fill that address range.

`LOG` *ddcu*`:` [[*d*`:`*path*`\`]*filename*[`.LOG`]] [*switches*]

Logs the activity of the specified PDP-11 device to a file. The default filename extension is "`.LOG`". For character devices, all output sent to that device is logged. For all others, commands sent to the device are logged to the file, with a timestamp on each one. If no filename is specified, any existing log file for that device is closed. The available switches are as follows:

> `/APPEND` appends to an existing log file, rather than replacing it.
>
> `/LAST:`*n* limits the log file to only the last *n* lines of log data (or possibly fewer, if that many lines won't fit in the internal buffer).
>
> `/NOBUFFERING` disables multi-line buffering so that the internal log buffer is flushed to the file after each line-feed character. This causes increased disk activity (especially when combined with `/LAST`) but can be useful in diagnosing a crash.
>
> `/NOTIMESTAMPS` omits the timestamps on each command. This can be useful when using a file-compare utility on log files from two runs to look for differences. This switch has no effect on character devices, since they never log timestamps.
>
> `/PC` includes the value of the PDP-11 program counter when the command was initiated.

`LOG` *ddcu*`:` [[*d*`:`*path*`\`]*filename*[`.LOG`]] [*switches*]
(where *dd* is `LP` or `TT`.)

Logs all output to the specified character device in the specified file.

`LOG` *ddcu*`:` [[*d*`:`*path*`\`]*filename*[`.LOG`]] [*switches*]
(where *dd* is `CT`, `DB`/`DR`, `DC`, `DF`, `DK`, `DL`, `DM`, `DO`, `DP`, `DS`, `DT`, `DU`, `DX`, `DY`, `HD`, `II`, `IX`, `KD`, `KG`, `KP`, `MM`, `MS`, `MT`, `MU`, `PD`, or `XU`.)

Logs commands sent to the TA11, RMxx/RPxx, RC11, RF11, RK11D, RL11, RK611, host file device, RP11C, RS03/04, TC11, MSCP controller, RX11, RX211, `HD_SYS.EXE` pseudo-controller, DIP11A, IEU11A, M8644, KG11A, KW11P, TM03, TS11, TM11, or TMSCP controller, RXT11, or DU11 to the specified file. The unit number is insignificant (except for Massbus devices, which effectively have separate controllers for each unit); all commands to the controller are logged regardless of the currently selected unit.

`LOG XE`*n*`:` [[*d*`:`*path*`\`]*filename*[`.LOG`]] [*switches*]
`LOG XH`*n*`:` [[*d*`:`*path*`\`]*filename*[`.LOG`]] [*switches*]
`LOG NI`*n*`:` [[*d*`:`*path*`\`]*filename*[`.LOG`]] [*switches*]

Controls logging of Ethernet events. If a filename is specified then the log file is opened. These devices support additional switches specifying which events are to be logged. "`/`[`NO`]`COMMANDS`" controls logging of port commands, "`/`[`NO`]`RECEIVE`" controls logging of received frames, and "`/`[`NO`]`TRANSMIT`" controls logging of transmitted frames. The switches may be specified when the log file is first opened, or later in `LOG` commands with the filename parameter missing to change what is being logged without having to open a new log file. If neither the filename nor any switches are specified, any existing log file for that device is closed. If no switches are specified when the file is first opened, the default is "`/RECEIVE /TRANSMIT`".

`MAP` [*/switches*] *addr*

Displays the physical address corresponding to the specified virtual address. The switches to specify the virtual address space are the same as the ones used with the EXAMINE command.

`MOUNT` *pdp11dev*`:` [*pdp11switches*] *pcdev* [*pdp11switches and/or pcswitches*]

Mounts a PC file or device as the specified PDP-11 block device. The PDP-11 disk/tape controller of the appropriate type is created if it did not already exist.

pdp11dev is the name of the PDP-11 device name being created. It conforms to the syntax defined in section 1.8. The first two letters define the controller type, and are generally the same as the PDP-11 operating system's name for that device.

pcdev is the name of the PC device or filename to be used to emulate this particular PDP-11 drive. The possible names are described in chapters 4 and 5.

Switches specific to the controller type may appear either after the PDP-11 device name or after the PC device (or file) name, and are typically used to specify the drive type in case the controller supports more than one drive type. If no drive type switch is specified, the default type is usually based on the size of the PC device. All emulated controller types support the "`/RO`[`NLY`]" (syn. "`/WP`[`ROTECT`]") switch, which has the same pressing the `WRITE PROT` (etc.) button on a real drive, and works even in cases like the RX01 where the real hardware had no write protection facility. A "`/RW`" switch exists for completeness and allows read/write access to the device, which is the default behavior. See chapters 4 and 5 for more information.

Just like `ASSIGN`, `MOUNT` commands also work with a range of unit numbers in *pdp11dev*. If the PDP-11 device name ends with a low–high range of unit numbers (i.e. two numbers separated by a hyphen), every unit in that range is created at once. Again, *pcdev* should have only the unit number of the first unit in the range, for devices where that makes sense, and the number will be incremented automatically for every device (or filename) in the range. For devices that don't have unit numbers, like "`RAM:`" and "`NULL:`", all the units come out the same.

`PRIMARY` *n*

Switches the session number (in the range 1–12) being displayed on the primary (or only) video monitor. This command is equivalent to pressing Alt-F*n* on the keyboard, except that it may be issued from an initialization file or serial console without requiring that key combination to be typed manually on the PC keyboard.

`PROCEED` [*break*]

Continues PDP-11 execution at the address currently in the program counter. If "*break*" is specified, then it is the virtual address of a single hard breakpoint, where the PDP-11 is guaranteed to stop if an instruction fetch is attempted starting at that address, regardless of what mode the computer is executing in, and regardless of whether the contents of that location have changed since the breakpoint was set. This can be handy for tracing code that hasn't been loaded yet. Note that hard breakpoints and single stepping with the `STEP` command interfere with the operation of the PDP-11 T bit, so don't combine them with a debugger (or CPU traps diagnostic program) running on the PDP-11 or you'll get strange behavior.

`QUIT`

Exit the simulator, closing all image and log files and resetting all devices that were in use.

`REGISTER` [*r val*]
reg=*val*
flag=*val*

If "*r*" and "*val*" are given, sets register "*r*" (0–7) in the current register set to contain "*val*." Otherwise displays the values of all eight registers, the condition codes, the current and previous processor modes, and the current interrupt priority level. Registers and condition code flags may also be set by typing the register name, an equals sign, and the new value at the command prompt. Any expression that works with `CALCULATE` is valid in this case,

so for example one may type "PC=PC-2." The CPU priority may be set in the same way using "PRIO= *val*", where *val* is from 0 to 7. Also the current mode and previous mode may be set with "CM=*x*" and "PM=*x*", where *x* is K, S, or U for kernel, supervisor, or user mode. Or the entire processor status word may be set at once with "PS=*xxxxxx*".

SECONDARY *n*

Switches the session number (in the range 1–12) being displayed on the secondary video monitor (if any). This command is equivalent to pressing Ctrl-F*n* on the keyboard, except that it may be issued from an initialization file or serial console without requiring that key combination to be typed manually on the PC keyboard.

SET BREAK {*nnn* | NONE}

Sets the octal value of an ASCII character that can be used in place of a serial BREAK signal to pop up an E11 prompt. For example, "SET BREAK 020" will cause any CTRL/P character typed on TT0: to bring up an E11 prompt. The default value is "NONE", meaning that all ASCII characters are passed through and only a serial BREAK, or a keyscript PROMPT command, will bring up the prompt. This command is intended for use in cases where the console (TT0:) has been ASSIGNed to a real serial port, connected to a terminal (or terminal program) that has difficulty generating BREAK signals.

SET CLOCK 14318*nnn*

Informs E11 of the actual frequency (in Hertz, as a decimal number) of the PC motherboard's 14.318 MHz system clock used to derive the 50/60 Hz clock, among other things. This frequency is supposed to be 14318180 Hz (which is what E11 assumes by default), but if your PDP-11 OS's clock gains or loses time at this setting due to the oscillator frequency being slightly off, you can use SET CLOCK to make slight changes, and E11 will adjust its math accordingly. The correct value can be determined experimentally, or measured using test equipment (this would require a very accurate frequency counter to be useful though). Setting values wildly different from 14318180 may produce unexpected results.

SET CPU *item* [*item* ...]

This command changes the emulated CPU type, either by changing to a new model all at once, or on a feature-by-feature basis. Each keyword enables a particular feature, or disables it if preceded by "NO". Any number of keywords may be specified in one line, and they are applied left to right. For example, "SET CPU 44 NOFPP" will create a PDP-11/44 and then delete its floating point processor. This gives you the ability to roll your own CPU, which need not correspond to any actual existing PDP-11 model. Changing the CPU's type while it is running will work but is likely to crash the PDP-11 operating system under some cases. SHOW CPU displays the current settings of all options.

E11 does not really emulate cache memory, since that would greatly slow down emulation rather than speeding it up. Maintenance features such as "write wrong parity" are not emulated either, since again they would needlessly add huge overhead and anyway since the data paths being tested by these modes are all different on a PC, PDP-11 diagnostic software would not gain any useful information by exercising them. So for these cases E11's emulation is limited to creating the appropriate registers in the I/O page so software can read and write them without losing data or receiving unexpected bus timeout errors. Note that if RSTS/E sees a parity CSR or KTJ11B maintenance CSRs it attempts to exercise them, giving a fatal error if they do not work. To avoid this problem, the CPU configuration given by SET CPU 94 has NOKTJ11B and NOPARCSR by default as a workaround. These CSRs may still be enabled for software that needs them with SET CPU 94 KTJ11B PARCSR, however both RT-11 and RSX11M+ will work with the default setting.

SET CPU options:

number Set all CPU options to match PDP-11/*number* model. Recognized values are 03, 04, 05 (syn. 10), 15 (syn. 20), 23, 24, 34, 35 (syn. 40), 44, 45 (syn. 50 or 55), 53, 60, 70, 73, 74,

83, 84, 93, 94.

ASH31	J11 CPU bug with 31-bit shifts using ASH/ASHC.
ASR	KDJ11E additional status register (TOY clock etc.).
CB	Cache bypass bit in Unibus map registers.
CCR	Cache control register (at (17)777746).
CD	Cache disable bit in PDRs.
CDR[=*n*]	KDJ11x configuration/display register (at (17)777524), *n* is 8-bit DIP switch value.
CHR	Cache hit register (at (17)777752).
CHRNZ	If CHR is present, reads as non-zero.
CMDR	PDP-11/44 cache memory data register (at (17)777754).
CPUERR	CPU error register.
CSM	CSM instruction (requires SUPMODE to work).
DESTFIRST	Evaluate destination operand first in dual operand instructions with mode 0 source. Effect is to use incremented/decremented value of register as source with mode 2–5 destination using same register, or PC+2 for mode 07 source and mode 67 or 77 destination.
DSPACE	Split I/D space.
DUALREGSET	Dual register set.
EAE	KE11A/B Extended Arithmetic Element.
EIS	Extended (integer) Instruction Set.
EIS16	EIS instructions with odd destination set condition codes based on 16-bit result.
FIS	Floating Instruction Set (FIS option for PDP-11/35,40 and LSI-11).
FPA	Floating point accelerator, sets KDJ11x MR bit indicating FPJ11 present.
FPBACKOUT	J-11 SR1 behavior, autoinc/dec is always undone on aborted FPP instruction.
FPP	FP11 floating-point instruction set.
HALT4	HALT in user mode traps to 4 instead of 10.
IOPAGE4	I/O page is only 4 KB with MMU disabled (for PDT-11s).
JMP4	JMP R*n* or JSR R*n* traps to 4 instead of 10.
JMPPLUS2	JMP (R)+ and JSR X,(R)+ jump to incremented value of R (R+2).
KTJ11B	KTJ11B Unibus adapter maintenance registers.
LDUB	PDP-11/60 LDUB instruction (load microbreak register), as no-op.
LKS	LKS clock status register (at (17)777546).
LKS7	Bit 7 (monitor) of LKS clock status register is mechanized.
LOCKASRB	ASRB instruction uses interlocked memory access.
MARK	MARK instruction.
MAS	PDP-11/60 MAS instruction (maintenance alignment shift), as no-op.
MBR	PDP-11/70 microprogram break register (at (17)777770).
MED	PDP-11/60 MED instruction (maintenance examine/deposit), as no-op.
MFPT[=*n*]	MFPT instruction (returns *n* in R0).
MNS	PDP-11/60 MNS instruction (maintenance normalization shift), as no-op.
MPP	PDP-11/60 MPP instruction (maintenance partial product), as no-op.
MSEA	Memory system error address register (at (17)777740/2).
MSER	Memory system error register (at (17)777744).
MMTRAPS	PDP-11/45,55,70-style memory management traps, 3-bit ACF.
MMU	Memory management unit, MFPD/MFPI/MTPD/MTPI instructions.
MMU22	22-bit MMU (must use UMAP too if emulating Unibus CPU).
MR[=*n*]	Maintenance register (at (17)777750). If *n*<16., KDJ11x-style maintenance register which reads *n* as model code in bits 7:4. If *n*=44, PDP-11/44 style MR, and if *n*=70, PDP-11/70 style MR.
MXPS	MFPS, MTPS instructions.
ODD	Odd address trapping.
PARCSR	Parity/ECC memory CSR address (at (17)772100).
PCR[=*x*]	KDF11/BDV11 page control register and read/write register if *x*="KDF11", or KDJ11 CSR/page control register if *x*="KDJ11" (at (17)777520/2).
PDRA	Working "A" bit (bit 7) in MMU PDRs. PDP-11/45,50,55 and PDP-11/70 only.

PDRW	Working "W" bit (bit 6) in MMU PDRs. All PDP-11 MMUs have this bit, but if the PDP-11 operating system doesn't need it, disabling it may yield a small improvement in emulation speed.
PIRQ	PDP-11/45-style 7-level software interrupts.
PRIO	Multiple interrupt priority levels (as opposed to the PDP-11/03's single level).
PSWIO	PSW accessible from I/O space (at (17)777776).
QBUS	Q-bus exists (otherwise Unibus). Affects default models and default interrupt priorities of many emulated peripherals.
RTIRTT	`RTI` instruction works like `RTT` (early CPUs).
RTT	`RTT` instruction.
SIZE	PDP-11/70 system size registers (at (17)777760/2).
SOBSXT	`SOB`, `SXT` instructions.
SPL	`SPL` instruction.
SR	Switch register/display register (at (17)777570).
SR1	MMU status register 1.
STACKLIM	PDP-11/70 stack limit register (at (17)777774).
SUPMODE	Supervisor mode.
SWABV	`SWAB` instruction preserves V bit.
SYSID[=*n*]	PDP-11/70 system ID register (at (17)777764), returns *n* when read.
TSTSET	J-11 `TSTSET`, `WRTLCK` instructions.
UMAP	Unibus map (maps 18-bit I/O bus to 22-bit memory).
UNDOAUTO	Undo mode 2/3 autoincrements on bus error etc.
UPCSR	PDT-11 USART parameter CSR (at (17)777420).
USERMODE	User mode (or anything besides kernel mode).
UWIN	Unibus appears in address window at 17000000.
XOR	`XOR` instruction.

`SET DELAY` *device* c_1`:`n_1 c_2`:`n_2 ...
`SET DELAY` *device* `*:`n

Sets the number of instructions that the specified command opcodes appear to take to complete on the indicated device. The *device* may be `DELQA`, `DELUA`, `DL11`, `HOSTFILE` (the host file access pseudo-device), `KW11L`, `LP11`, `PC11`, `RC11`, `RF11`, `RK11D`, `RK611`, `RL11`, `RP11C`, `RS03` or `RS04` (synonyms), `RX11` or `RX211` (synonyms), `TA11`, `TC11`, `TM03`, `TM11`, or `TS11`. There may be an arbitrary number of parameters of the form "c`:`n" or "c`=`n", where c is the octal opcode for the command (or "`*`" for all commands for this device) and n is the decimal number of PDP-11 instructions to delay before signaling completion of the command.

The reason that device commands, such as "*read sector*" on an RX02, or "*transmit character*" on a DL11, delay signaling completion (by raising a "*ready*" flag and/or triggering an interrupt) instead of completing right away (which would seem natural in an emulator) is that some OS software contains assumptions that at least a certain number of instructions are guaranteed to be executed before a device is able to interrupt, even when interrupts from that device are enabled. The default interrupt delays are set for the "worst case", so that each one is long enough to avoid any known (or suspected) problems with DEC OS software. The `SET DELAY` command may be useful in cases where your OS needs a longer delay than the default, or in cases where your OS's treatment of a device is "clean" and you can gain a noticeable I/O speed increase by setting all the delays for that device to 1, or in cases where you're debugging OS software and want to test against variety of interrupt rates.

Note that some devices don't have numbered command opcodes per se, but the `SET DELAY` command syntax requires one anyway for consistency, and pseudo opcode numbers are assigned if necessary. On DL11 SLUs, opcode "0" refers to the delay between reading a character from the receiver buffer, and getting the interrupt for the next character (only if it's the second or later character of a function key sequence on an emulated VT100, all other keyboard interrupts correspond to actual asynchronous events). Opcode "1" refers to the delay between writing a character to the transmitter buffer, and getting the completion interrupt (for emulated VT100s — COM and LPT ports use real completion interrupts). Similarly, PC11 opcode "0" refers to how long it takes to read a character

from paper tape, and opcode "1" refers to how long it takes to write one. An LP11 has only one opcode, which is "0" and corresponds to the same thing as opcode "1" of a DL11. An RK611 has only opcodes 0–17, but the SET DELAY command defines an opcode "20" which refers to the delay between the interrupt that acknowledges reception of a head movement command (which is itself delayed), and the "attention" interrupt which signals completion of the head movement. The RK11D emulation has a similar dummy opcode "10" which means the same thing, and the TA11 emulation has a dummy opcode "10" which defines the delay between character interrupts within a block. A KW11L has no opcodes, so opcode "0" sets the delay between simulated interrupts which are used to catch up if clock interrupts are missed due to native PC file I/O taking more than 16.67 ms (or 20 ms in 50 Hz clock mode) to complete.

SET DISPLAY NONE
SET DISPLAY PORT *n*
SET DISPLAY LPT*n*:

If PORT is specified, specifies the 80x86 I/O address (as an expression with the same syntax as used by the CALCULATE command) of a word port which when written as a word, sets the 16-bit display register. Building the trivial hardware to support this is left as an exercise to the reader.

If a PC LPT port name is given, it specifies a port which has a multiplexed LED board plugged into it, and E11 will refresh each half on alternate 60 Hz (50 Hz) clock ticks. There's a little flicker but it works and requires no chips or power supply. Just build your board so that the D0–D7 lines (pins 2–9 of the DB25) drive the anodes of the both the D0–7 and D8–15 LEDs (through the same set of eight 100 ohm resistors since only one set of LEDs will have their cathodes grounded at a time). Then add two NPN switching transistors (2N3904 etc.), one for each byte, with the emitters grounded (pin 25), each collector connected to the cathodes of all 8 LEDs for the appropriate byte, and the bases connected through 1 K current limiting resistors to $\overline{\text{STROBE}}$ (pin 1) for the D0–D7 side, or $\overline{\text{INIT}}$ (pin 16) for the D8–D15 side. A bare PC board is available from D Bit at cost ($14.68 plus shipping for the current batch, still lying around since December 1994).

If NONE is specified, then the current DR value is available only from the SHOW DISPLAY command (the default condition).

SET DISPLAY {DR | BDR | R0 | PC}

Sets what register is displayed on a hardware LED display register (either the parallel port kind described above or the kind that plugs into a bus slot and is addressed by a word OUT instruction). By default the DR is displayed (i.e. the last word written to (17)777570), but the BDR (boot/diagnostic display register, i.e. the last byte written to (17)777524), or R0 or the PC may be selected instead, since the null jobs in some operating systems display a pattern in R0 (and the PC in some cases) during a WAIT instruction. The pattern may be used to get a rough idea of system load, and the R0/WAIT method is a standard way to display a number on the PDP-11/70, which has no display register address. For completeness, registers R1–R5 or SP may be selected too.

SET HERTZ {50 | 60}
SET HZ {50 | 60}

Sets the frequency of the KW11L line clock (startup default is 60). Ersatz-11 reprograms the PC timer chip for this rate to simulate line time clock interrupts, and then maintains a count in software so that it knows when to trigger BIOS 18.2 Hz interrupts; there is some jitter due to the BIOS interval being rounded down to the previous KW11L interrupt, but there is no cumulative error so the DOS clock is still correct when you exit from E11.

SET IDLE [DELAY=*n*] [[NO]RELEASE]

Sets the behavior when the emulated CPU is idle, i.e. halted or executing a WAIT instruction. RELEASE means to ask the host OS to release the current time slice. This way E11 won't hog 100% of the host CPU's time for no reason. However, in OS/2's DOS box this is taken as a sign that E11 will be idle for some time so its priority gets

reduced as a result, so this option should not be used in OS/2. NORELEASE means E11 should just keep looping until there's something for it to do. DELAY=*n* causes a *n*-millisecond delay each time there's nothing else to do, which reduces the load on the PC operating system at the expense of increased response time.

SET KEYBOARD [NO]SWAP

SWAP sets the keyboard handler to exchange the functions of the Caps Lock and left Ctrl keys for people who don't like the IBM Enhanced Keyboard. NOSWAP sets the handler back so that the keys work as marked. The swap is made upstream of the keyscript interpreter, so CAPSLOCK and LCTRL execute each other's KEYPRESS and KEYRELEASE scripts when the keys are swapped.

SET MEMORY *nnnn*

Sets the size of emulated PDP-11 memory. *nnnn* is the number of kilobytes of memory, anything from 8 up to 4088 (or the limit specified by the /MEMORY:*n* switch when E11 was started).

SET PCLOG {ON | OFF | *n*}

Enables or disables logging of the PC (program counter) register's value before each PDP-11 instruction fetch, at a slight speed penalty. Used for debugging PDP-11 code. By default, the last 64 fetches are logged. SET PCLOG *n* enlarges this to any power of two that will fit in available memory (and implies SET PCLOG ON too). SHOW PCLOG displays the logged values.

SET [NO]SCOPE

Sets whether the console terminal is a scope or a hardcopy terminal, for the purpose of handling rubout characters typed at the "E11>" prompt. Mainly useful if the console is redirected to a COM port with a DECwriter (etc.) plugged into it. Also determines whether typing ^L at the command prompt will attempt to clear the screen.

SET SCROLL {HARD | SOFT}

Selects the mechanism used for video scrolling in emulated VT100 sessions. HARD scrolling offers superior performance (it works by programming the video board(s) to change the start address of the screen each time a full-screen scroll is needed), but may expose problems in video virtualization in GUI DOS boxes, or cause problems with TSRs that use the display. SOFT scrolling does things the slow obvious way, by copying the whole screen a line up on each line feed, and ought to work with anything. HARD scrolling is the default. You should try putting SET SCROLL SOFT in your E11.INI file if your display gets scrambled a few lines into each attempted E11 session.

SET SWITCH *n*
SET SWITCH PORT *n*

If PORT is specified, specifies the 80x86 I/O address (as an expression with the same syntax as used by the CALCULATE command) of a word port which when read as a word, gives the current 16-bit switch register value. Otherwise (PORT not specified), sets the value of the emulated SR to *n* (again as a CALCULATE-style expression).

SET THROTTLE [ON] [OFF] [DELAY=*usec*] [FILE=[*d*:*path*\]*filename*[.TAP]] [INTERVAL=*insts*]

Enables or disables a throttle which can slow down the average emulated CPU speed in a fairly predictable way, for compatibility with PDP-11 software which contains timing loops which are tuned for a particular PDP-11 CPU model. Timing is approximate, due to the added overhead of accessing the PC's clock hardware so often, but it should still be possible to get close.

The throttling is done by inserting delays at regular intervals during simulation of PDP-11 instructions.

DELAY=*usec* sets the length of this delay to a fixed value of approximately *usec* microseconds.

FILE=*filename* loads a table of 65,536 little-endian binary 32-bit values (from a 262,144-byte file), each of which is the number of nanoseconds that the corresponding PDP-11 opcode should take to execute, given in order from 000000 to 177777 octal. Entries with values above 50,000 are currently not allowed and produce a "value out of range" error message.

INTERVAL=*insts* sets the number of PDP-11 instructions that will be executed between delays.

So every *insts* instruction fetches, there will be a fixed delay of about *usec* microseconds (if DELAY was used), or a delay computed to bring the total amount of real time that the previous insts instructions took to execute up to the sum of those opcodes' entries in the table (if FILE was used).

The ON keyword turns throttling on. Throttling is also turned on implicitly when the DELAY=*usec* and/or INTERVAL=*insts* parameter(s) is/are given.

The OFF keyword turns throttling off, and allows PDP-11 instruction emulation to proceed at the maximum possible speed. This is the default setting.

SET *pcdevcu*: ...

Sets parameters for the specified PC device, with the optional controller letter and/or line number given using the usual device name syntax, see section 1.8. SET commands for real PC devices must be issued before the first ASSIGN or MOUNT command which uses that PC device. The PC device names are the same as those used on the right hand side of an ASSIGN or MOUNT command.

The rest of the command line consists of keywords appropriate to that device type. The valid SET parameters for each PC device type are listed in the section that describes that device. Multiple keywords may be specified on the same SET command, they will be processed in left-to-right order.

The following SET parameters are common to many PC devices:

IRQ*n* Sets the IRQ number (0–15) used by an ISA (or PCMCIA) board to generate interrupts.

PORT=*nnnn* Sets the base I/O port address (in 80x86 I/O space) used by the board. Numbers are hex by default as long as they start with a digit (0–9). An expression may be used, the same as with CALCULATE.

SHARE Specified after an IRQ*n* parameter, SHARE means that the device has special ISA IRQ sharing hardware (as documented in the *IBM AT Technical Reference Manual*) so that more than one device may use the same IRQ line at once. This hardware is relatively rare, so most devices do not support this option.

Note that without this hardware, no more than one device may be actively using the ISA IRQ at the same time. So for example if you have a mouse attached to COM1 using IRQ4 and it has been initialized by a mouse driver, E11 will not be able to use COM3 if it also uses IRQ4. An error message will be given if you try to issue an ASSIGN command for COM3.

SET commands are parsed left to right, and ISA IRQ sharing is disabled by an IRQ*n* keyword, so the SHARE keyword must appear to the right of the IRQ*n* keyword, or on a subsequent SET command.

PCI IRQ sharing works differently from ISA IRQ sharing, and does not need to be enabled explicitly with a SET command.

`SET` *ddcu*: ...

Sets parameters for the specified PDP-11 device. Possible parameters are as follows:

`BOOT=`*option*	Selects whether incoming *MOP* boot frames will be honored. Specifies either the `BOOT` command parameters, or `DISABLED` (default) to disable network-initiated booting.
`CSR=`*nnnnnn*	Sets the base CSR address to *nnnnnn* octal.
`CSR=DEFAULT`	Sets the base CSR address back to the default address for this device (useful if it had been changed with an earlier `SET` command). `SHOW` commands will display "(D)" after an address which was chosen using `DEFAULT`.
`CSR=FLOATING`	Sets the base CSR address according to the PDP-11 floating CSR rules, for devices that support this scheme. CSR addresses for all floating devices are recomputed every time the device configuration is changed. `SHOW` commands will display "(F)" after an address that was chosen using `FLOATING`.
ctrltype	Set controller type. This is mainly used to distinguish between Unibus and Q-bus versions of controllers, which differ in number of address bits used and whether they go through the Unibus map, and in some cases in other ways as well. `DEFAULT` means to choose a default controller type based on whether `SET CPU QBUS` is in effect. `SHOW` commands will display "(D)" after a controller type which was chosen using `DEFAULT`.
`DS/SS`	Sets the disk to be single-sided or double-sided. Real RX211s autodetect this but 3.5" and 5.25" disks don't have a separate index hole for DS disks, so the number of sides must be set explicitly.
`MODE`	Sets the mode parameters for the specified port using a syntax similar to the DOS MODE command. The four parameters "*bps*`,`*par*`,`*dbits*`,`*sbits*" set the decimal number of bits per second (which unlike DOS MODE, may not be abbreviated, so "96" really means 96 baud not 9600), a single letter indicating the parity ("E" for even, "O" for odd, "N" for none, "M" for mark, "S" for space), a decimal number of data bits (5–8), and a decimal number of stop bits (1–2). This is mainly useful for DL11 type ports where the communications parameters are not set by software, for mux ports any parameters set with `SET MODE` will be overridden by the values written to the mux by the driver in the PDP-11 OS, unless they are locked with the `LOCK` option. Note that the set of valid baud rate values depends on the hardware emulating that port. If the value specified is not available E11 will use the closest rate the device supports.
`PRIORITY=`*n*	Sets the interrupt priority to *n* (4–7).
`PRIORITY=DEFAULT`	Sets the interrupt priority to DEC's default value for this controller type. In many cases, the original Unibus version of a controller uses priority 5, but the Q-bus equivalent uses priority 4, since early LSI-11 CPUs didn't have a multi-level priority system. When set to DEFAULT, the priority will normally be automatically reduced to 4 when emulating a Q-bus CPU. This is true even on devices which were available from dDEC only for Unibus, since there may have been aftermarket Q-bus versions which used priority 4.
`READONLY`	Write-protect a disk or tape unit.
`READWRITE`	Write-enable a disk or tape unit.
`REWIND`	Rewind the paper tape, or card deck, so that subsequent input will start over at the beginning of the file.
`RH11`	Sets this Massbus adapter (specified by controller letter; unit number is unimportant) to be an RH11. 18-bit addressing, goes through Unibus map if one is configured with `SET CPU UMAP`.
`RH70`	Sets this Massbus adapter to be an RH70. 22-bit absolute addressing, RHBAE/RHCS3 registers exist.

`VECTOR=`*nnn*	Sets the base vector address to *nnn* octal.
`VECTOR=DEFAULT`	Sets the base vector address back to the default address for this device (useful if it had been changed with an earlier `SET` command). `SHOW` commands will display "(D)" after an address which was chosen using `DEFAULT`.
`VECTOR=FLOATING`	Sets the base vector address according to the PDP-11 floating vector rules, for devices that support this scheme. Vector addresses for all floating devices are recomputed every time the device configuration is changed. `SHOW` commands will display "(F)" after an address that was chosen using `FLOATING`.

`SHOW ASYNCPORTS`

Lists the asynchronous serial ports that have been detected on this system, and the host-OS-independent nicknames that may be used to access them with `ASSIGN` commands. The last entry is always `NULL:`, to ensure that there's always at least one valid `ASYNC`*n*`:` unit.

`SHOW BDR`

Shows the current value of the boot/diagnostic display register (last value written to (17)777524).

`SHOW BREAK`

Shows the octal ASCII value of the character that can be used in place of a serial BREAK signal to bring up the E11 prompt. The default is NONE, meaning that only a genuine serial BREAK signal, or PROMPT keyscript command (normally generated with Shift/Enter), will bring up the prompt, and all ASCII characters are passed through.

`SHOW CLOCK`

Shows the current assumed frequency (in Hz) of the PC motherboard's 14.318 MHz clock, used to generate the KW11L/KW11P 50/60 Hz clock.

`SHOW CPU`

Shows emulated CPU type, number of emulated CPUs if greater than one, and emulated core size, along with breakdown of features, as well as the CPU type of the host processor.

`SHOW CSR` *addr*

Shows the name of the device register at the specified octal I/O page address.

`SHOW DELAY` *device*

Shows the currently active list of interrupt delay counts for the specified device, starting with the delay for opcode number 0. See `SET DELAY` for details.

`SHOW DEVICES`

Displays a list of all emulated PDP-11 devices in the current configuration.

`SHOW DIGPORTS`

Lists the digital I/O ports (including LPT ports) that have been detected on this system, and the host-OS-independent nicknames that may be used to access them with `ASSIGN OA:` or `ASSIGN XA:` commands. The last

entry is always NULL:, to ensure that there's always at least one valid DIG*n*: unit.

SHOW DISPLAY

Shows the current value of the display register (last value written to (17)777570).

SHOW GPIBPORTS

Lists the GPIB (IEEE-488 instrument bus) ports that have been detected on this system, and the host-OS-independent nicknames that may be used to access them with ASSIGN IX: commands. The last entry is always NULL:, to ensure that there's always at least one valid GPIB*n*: unit. Actually, for the time being, NULL: is the only GPIB device.

SHOW HERTZ
SHOW HZ

Shows the current frequency, in Hz, of the emulated KW11L line clock. The default is 60.

SHOW IDLE

Shows the SET IDLE setting, either RELEASE (release the host CPU when idle) or NORELEASE (keep polling until there is something to do).

SHOW KEYPRESS *keyname*
SHOW KEYRELEASE *keyname*

Shows the keyscript currently bound to the keypress or keyrelease event for the specified key, if one is defined. See section A.3 for key names.

SHOW LED *ledname*

Shows the name of the flag (from the keyboard script language) whose value is being tracked by the specified LED, or "NONE" if the LED has been disabled. LED names are CAPS, NUM, and SCROLL. See section A.4 for a list of flag names.

SHOW MEMORY

Shows the amount of PC memory used by Ersatz-11, how much of that memory is emulated PDP-11 memory, and how much PC memory is free. Free memory must be available in order to use the ASSIGN, DEFINE KEYPRESS, LOG, or MOUNT commands.

SHOW MMU [{KERNEL | SUPERVISOR | USER} [INSTRUCTION | DATA]]

Shows the current mapping registers for the specified space. Defaults are KERNEL and INSTRUCTION space.

SHOW MOUSEPRESS *keyname*
SHOW MOUSERELEASE *keyname*

Shows the keyscript currently bound to the press or release event for the specified mouse button, if one is defined. See section A.3 for key names.

SHOW NICS

Shows the list of network interface cards available on this system. "ETH*n*:" nicknames are displayed for each port.

These may be used in ASSIGN commands as (possibly shorter) synonyms for the indicated internal port names.

SHOW PCI [*bb-dd-f*]

Shows a table of all PCI devices in this system. If a "*bb-dd-f*" bus/device/function value is specified (as three hexadecimal numbers separated by hyphens), the command shows more detailed information about that particular device.

SHOW PCLOG

Shows the log of PC (program counter) values from the last 64 PDP-11 instruction fetches, if enabled with SET PCLOG ON (or more, if enabled with SET PCLOG *n*). Used for debugging PDP-11 code.

SHOW PRINTERPORTS

Lists the printer ports that have been detected on this system, and the host-OS-independent nicknames that may be used to access them with ASSIGN commands. The last entry is always NULL:, to ensure that there's always at least one valid PRINT*n*: unit.

SHOW SYNCPORTS

Lists the synchronous serial ports that have been detected on this system, and the host-OS-independent nicknames that may be used to access them with ASSIGN commands. The last entry is always NULL:, to ensure that there's always at least one valid SYNC*n*: unit.

SHOW THREADS

Shows a list of all threads currently running in Ersatz-11, and a brief description of each one. This command is mainly intended as a support aid when contacting D Bit for help. This command gives no meaningful output unless the system is emulating a multi-processor PDP-11.

SHOW THROTTLE

Shows the current status of the emulated CPU speed throttle. See the SET THROTTLE command for more information.

SHOW VERSIONS

Shows the version numbers of Ersatz-11, the host operating system, and any other relevant interfaces.

SHOW VIDEO

Shows video adapter parameters. Displays the types of the primary and secondary display adapter boards. For SuperVGA boards with a VESA BIOS, shows the VESA BIOS Extensions version number and the vendor string. For EGA, VGA, and SuperVGA boards, lists all the text-mode screen dimensions available on this particular board. These are the dimensions which may be used on an "ASSIGN ... CON*n*: /SIZE: *W*x*H*" or "SET CON*n*: SIZE=*W*x*H*" command, or in an "E11 /CONSIZE: *W*x*H*" switch.

Note that in order to detect the text modes and version/vendor information, E11 must call the VESA BIOS, which will cause Windows to switch the DOS box to full-screen mode if E11 is running in a DOS Window. This happens the first time this command is typed, or whenever a CON: screen is put into a text mode other than the standard IBM EGA/VGA modes.

SHOW *ddcu*:

Shows the configuration of the specified PDP-11 or PC device. The actual data shown are dependent on the device type, in general the display contains the information that can be `SET` for that device (e.g. controller type, interrupt priority, or CSR/vector addresses), and for PDP-11 devices the name of the PC file or device attached with `ASSIGN` or `MOUNT` is shown. Not all devices support `SHOW`.

Unit-number ranges are accepted in PDP-11 device names, to show multiple devices with one command.

In the output from a `SHOW` *ddcu*`:` command, "(D)" following a controller type or interrupt priority means that parameter is set to "DEFAULT" and the displayed type or priority is the default based on the "SET CPU [NO]QBUS" setting. Similarly, "(F)" following a CSR or vector value means that parameter is set to "FLOATING" and the value given is the one currently in use based on the system configuration.

The default controller types, floating CSR or vector addresses, and default interrupt priorities are assigned specific values only for controllers that have actually been created with an `ASSIGN` or `MOUNT` command. If the controller does not currently exist then a defaulted controller type or interrupt priority will simply be listed as "DEFAULT" and floating addresses will be listed as "FLOATING".

The following PC devices support SHOW: `A:`/`B:`/etc. (floppy drives), `CON`*n*`:`, `COM`*n*`:`, `LPT`*n*`:`, `NE2000`*c*`:`, `PCNET`*c*`:`, `RTL8139`*c*`:`, `RTL8169`*c*`:`, `TULIP`*c*`:`, `VELOC`*c*`:`.

Examples:

Show a PC device:
```
E11>show com1:
COM1: PORT=^X03F8 IRQ4
```

Show a simple PDP-11 device:
```
E11>show tt0:
TT0: CON1:
 CSR=777560(D) VECTOR=060(D) PRIORITY=4
```

Show an auto-configuring unmounted PDP-11 device:
```
E11>show dl0:
DLA0: NONEXISTENT
 DEFAULT CSR=17774400 VECTOR=160 PRIORITY=DEFAULT
```

Mount the device and show it under a Unibus emulation (PDP-11/70):
```
E11>mount dl0: \e11\rt11
E11>set cpu 70
E11>show dl0:
DLA0: RL02 READ/WRITE FILE "C:\E11\RT11.DSK"
 RL11(D) CSR=17774400(D) VECTOR=160(D) PRIORITY=5(D)
```

Switch to a Q-bus emulation (PDP-11/93) and show changes:
```
E11>set cpu 93
E11>show dl0:
DLA0: RL02 READ/WRITE FILE "C:\E11\RT11.DSK"
 RLV12(D) CSR=17774400(D) VECTOR=160(D) PRIORITY=4(D)
```

`STEP` [*count*]

Executes the specified number (default=1) of single instruction steps and displays the updated registers after each. Note that if real time clock interrupts are enabled and the CPU priority is below 6, `STEP` will immediately enter the clock interrupt service routine instead of executing the instruction at the current PC. An easy workaround is to

disable clock interrupts with "`D 17777546 0`" before using `STEP`, and then reenable them with "`D 17777546 100`" before continuing regular execution.

`TYPE` [*d*:][*path*]*filename*

Types the specified PC text file on the screen. The display pauses at the end of each screen. Typing "Q" (or CTRL/C) ends the listing, carriage return advances by one line, and any other character advances to the next screen.

`UNLOAD` [*/switches*] [*address*]

Unloads a ROM or EEPROM page previously loaded with "`LOAD`". Either the "`/ROM`" or "`/EEPROM`" switch is required, "`/BANKED`" may be given to invoke the default starting addresses of (17)773000 for "`/ROM`" and (17)765000 for "`/EEPROM`", otherwise the starting address of the ROM must be given.

Appendix A

Keyboard Script Language

The script language used by E11's `DEFINE KEYPRESS` and `DEFINE KEYRELEASE` commands (and `DEFINE MOUSEPRESS` and `DEFINE MOUSERELEASE`) is powerful, yet very easy to use. Unlike some systems where keys can have only characters or strings bound to them, and mouse buttons can be reordered but not changed, E11 allows the user to attach a small script to each key so that more complicated operations can be defined. In particular, there's nothing special about the shift keys (Ctrl, Alt, Shift); they can be redefined to be data keys and vice versa.

When defining a new keyscript, it may be helpful to use a `SHOW` command to display the existing default keyscript for that key, or a similar one, and use it as the basis for writing the new keyscript. To make the keyboard send a character or string to the system, simply enclose that character or string in single or double quotes. `IF` statements can be used to send different strings depending on the state of a variety of flags (including the current state of the Alt, Ctrl, and Shift keys).

`NONREPEATING` and `NOREPEATS` commands are used in many of the default keyscripts to emulate the autorepeat behavior of the VT100 keyboard precisely. `NONREPEATING` tells E11 that this keyscript should not be autorepeated even if the key is held down (like the VT100 Esc, Tab, and Return keys), and `NOREPEATS` means that while this key is pressed, all other keys should be prevented from autorepeating (which is what the VT100 Ctrl key does). There are numerous other special-purpose commands that allow such things as sending the current date and/or time in a variety of formats, popping up the E11 command prompt, and switching the video display to show another session.

Multiple statements in a single key definition may be separated by ":" or "\" characters and count as one statement (for the purposes of the `IF`/`ELSEIF`/`ELSE`/`ENDIF` construct). If a line ends with "&" (with no white space following) it is continued on the next line, and any characters after the first "!" that is not inside single or double quotes are considered a comment and are ignored (up until the trailing "&" if one is present). This should be familiar to BASIC-PLUS users.

A.1 Default keyboard layout

The keypad layout generated by E11's predefined keyscripts may take a little getting used to but it's intended to be familiar if your fingers are already comfortable using KED or EDT on a real VT100. Just don't look at the keypad, the keys are where you expect in spite of having the wrong labels. Similarly, the CTRL characters on the main keyboard are in the same places as on a VT100, including the non-alphabetic ones (e.g. CTRL/SPACE generates NUL, CTRL/~generates RS, etc.). The "backspace" key generates DEL because that's what DEC operating systems normally use. Use CTRL/H to get a backspace character. Line feed is CTRL/J, and on 104-key keyboards it's

also the "context menu" key next to the right-hand Ctrl key.

The keypad digits and "." key work as marked (you must be in Num Lock mode to get this on 84-key keyboard, it doesn't matter on 101- or 104-key keyboards). The keys around the top and right edges of the keypad are *not* as marked, but correspond to the PF1–PF4, hyphen, comma, and ENTER keys of the VT100. The comma key is missing unless you have an 84-key AT keyboard. CVT *Avant Prime* and *Avant Stellar*, and Northgate *Omnikey 102* keyboards (which were all apparently designed by the same person) have an "=" key where the VT100 comma belongs but unfortunately there is no way for software to distinguish it from the =/+ key on the main keyboard so E11 can't use it as a comma, so F8 must be used instead. To get the normal function of the Num Lock key (and Esc, Scroll Lock, and Sys Req on an 84-key AT keyboard), press Alt, Ctrl, or Shift at the same time (it doesn't matter which). The VT100 keypad hyphen, comma, period, and ENTER keys are also available as the F6, F8, F9, and F10 keys (see below). On an IBM AT 84-key keyboard (which has the F-keys stacked vertically) this gives the same layout as the right-hand edge of a VT100 keypad.

If your keyboard has an F12 key, pressing it will send the current date and time in the format "*hh:mm:ss dd-mmm-yyyy*," unless you `DEFINE` it to do otherwise. This is intended to be useful when starting an RSX or IAS system.

CON1:	CON2:	CON3:	CON4:

CON5:	CON6: -	CON7:	CON8: ,

CON9: .	CON10: Enter	CON11:	CON12: Date

Default F-keys on 101- and 104-key keyboards

NumLock PF1	PF2	PF3	PF4
7	8	9	-
4	5	6	
1	2	3	Enter
0		.	

Default keypad layout on 101- and 104-key keyboards

Esc PF1	NumLock PF2	ScrLock PF3	SysReq PF4
7	8 ↑	9	-
4 ←	5	6 →	,
1	2 ↓	3	Enter
0		.	

Default keypad layout on IBM AT 84-key keyboards

CON1:	CON2:
CON3:	CON4:
CON5:	CON6: -
CON7:	CON8: ,
CON9: .	CON10: Enter

F-keys on IBM AT keyboards

A.2 Keyboard script statement descriptions

string

Sends the specified string. The string may be any combination of double quoted strings (`"`*string*`"`), single quoted strings (`'`*string*`'`), and single ASCII characters (`CHR$(`*n*`)`), all concatenated with plus signs (`+`). Note that PDP-11 serial ports normally have only one or two characters worth of input buffering, and E11 currently buffers 32 characters per port in addition to that (this number may increase in the future), so it is not possible to send

arbitrarily long strings.

`AMPM`

Sends "`AM`" or "`PM`" depending on whether the time read by `GETTIME` is before or after noon.

`ANSWERBACK`

Sends the answerback string (defined on the SET-UP B screen using Shift-A).

`BREAK`

Sends a BREAK (i.e. a NUL character with a framing error) to the PDP-11.

`CLEAR` *flag*

Clears a read/write flag. See section A.4 for a list of flag names.

`COPY`

Copies the currently selected text (see `SELECT` etc.) into the paste buffer, where it can be be pasted with `PASTE`.

`DAY1`

Sends the 1- or 2-digit day of the month (1–31) as read by `GETTIME`.

`DAY2`

Sends the 2-digit day of the month (01–31) as read by `GETTIME`.

`GETTIME`

Reads the current date and time (as an atomic operation to avoid race conditions) and stores it internally for use by `HOUR2`/`MINUTE2`/`SECOND2`) etc. `GETTIME` should be executed once before any sequence of commands that sends the various date/time fields. This is done explicitly, instead of having each individual command get the time itself before sending its field, in order to ensure that all the fields are coordinated and don't contain mismatched data if the clock rolls over while the date/time string is being composed. Without a preceding `GETTIME` statement, the statements that send the individual parts of the date/time will send garbage.

`HOUR1`

Sends the 1- or 2-digit hour of the day (0–23) as read by `GETTIME`.

`HOUR12`

Sends the 1- or 2-digit hour (1–12) as read by `GETTIME`.

`HOUR2`

Sends the 2-digit hour of the day (00–23) as read by `GETTIME`.

`HUNDREDTH2`

Sends the 2-digit hundredth of a second (00–99) as read by `GETTIME`.

```
IF <expr1> THEN &
 [statement1] &
ELSEIF <expr2> THEN &
 [statement2] &
 ...
ELSE &
 [statement3] &
ENDIF
```

Executes statements conditionally. The expressions may be made up of any combination of read-only and read/write flags (see section A.4 for a list of flag names), the operators `AND`, `NOT`, `OR`, and `XOR`, and parentheses (to override the default binary operator precedence, which is `NOT`, `AND`, and `OR`/`XOR` from highest to lowest with `OR` and `XOR` being equal).

If the expression after the `IF` is true, the statement (which may actually be multiple statements separated by ":" or "\" characters) following the `THEN` is executed, and after that execution then skips to after the `ENDIF`. Otherwise the expression following the `ELSEIF` (if any) is similarly tested, followed by any successive `ELSEIF`s if the first fails. Finally the `ELSE` clause (if any) is executed if no (`ELSE`)`IF` was true. This is pretty much the same as FORTRAN-77 or any language with block-structured `IF`s.

The `ELSEIF` keyword is provided as a convenience to avoid excessive nesting:

```
IF a THEN &
   x &
ELSEIF b THEN &
   y &
ELSE &
   z &
ENDIF
```

is equivalent to:

```
IF a THEN &
   x &
ELSE &
   IF b THEN &
      y &
   ELSE &
      z &
   ENDIF &
ENDIF
```

`LASTSIMILARYEARBEFORE` *year*

Changes the year stored by the last `GETTIME` to the last year before *year* that had all the same days of the week as the current year. The idea is that a `LASTSIMILARYEARBEFORE 2000` command may be used to run a non-Y2K-safe PDP-11 operating system and still get the correct day of the week in listings, reports, etc.

`LETTER` *string1*

Acts as a normal alphabetic ("letter") key. *String1* is a one-character string. If `CTRL` is true, *string1* is sent with the high 3 bits set to 0. Otherwise if `CAPS` or `SHIFT` is true then *string1* is sent with bit 5 set to 0. Otherwise *string1* is sent with bit 5 set to 1. This has the effect of converting it to lower or upper case as appropriate, and converting it to the correct control character if `CTRL` is true, assuming it's a US-ASCII alphabetic character.

`MILLISECOND3`

Sends the 3-digit millisecond (000–999) as read by `GETTIME`.

`MINUTE2`

Sends the 2-digit minute (00–59) as read by `GETTIME`.

`MONTH1`

Sends the 1- or 2-digit month (1–12) as read by `GETTIME`.

`MONTH2`

Sends the 2-digit month (01–12) as read by `GETTIME`.

`MONTH3`

Sends the 3-letter English month abbreviation (`Jan`–`Dec`) as read by `GETTIME`.

`NONDATA`

Specifies that the current key is not a data key and should not generate keyclick (if E11 supports it in the future) or count from a "`SET` *flag* `FOR` *n*" prefix.

`NONREPEATING`

Specifies that the current key should not auto-repeat.

`NOREPEATS`

Specifies that the current key should prevent all other keys from auto-repeating until it is released.

`NUMBER` *string2*

Acts as a normal numeric ("number") key. *String2* is a two-character string. If `CTRL` is true, nothing is sent. Otherwise if `SHIFT` is true then the second character of *string2* is sent. Otherwise the first character of *string2* is sent.

`PASTE`

Pastes the text from the paste buffer (as copied with `COPY`), as if it were typed at the keyboard.

`PRESS` *keyname*

Executes the "keypress" script for the specified key, i.e. the script defined by `DEFINE KEYPRESS` for that key.

`PRIMARY` *n*

Changes the screen on the primary video (or only) display to screen *n* (1–12).

`PROMPT`

Pops up an E11 command prompt. The primary video display is switched to `TT0:`'s screen if it is not already there.

`RELEASE` *keyname*

Executes the "keyrelease" script for the specified key, i.e. the script defined by `DEFINE KEYRELEASE` for that key.

`RSTSAMPM`

Sends "`AM`" or "`M`" or "`PM`" depending on the time read by `GETTIME`, using the unusual rules used by pre-V9.0 versions of RSTS/E:
00:00–00:00:59.99 is PM (the minute starting at midnight)
00:01–11:59:59.99 is AM as usual
12:00–12:00:59.99 is M (the minute starting at noon)
12:01–23:59:59.99 is PM as usual

`SCROLLBACK` {`BACKWARD | FORWARD`} {*n* | `SCREEN`}

Moves scrollback display backward or forward, either by `n` line(s) (where `n` is in the range 1–127) or by almost one screen.

`SECOND2`

Sends the 2-digit second (00–59) as read by `GETTIME`.

`SECONDARY` *n*

Changes the screen on the secondary video display to screen *n* (1–12). This is useful only on systems with two video displays, and performs no operation on systems with only one.

`SELECT`

Begin selecting text using the mouse. Text on the screen is shown in reverse video starting at the current mouse location, and extending to wherever the mouse moves, including into scrollback memory, until a `COPY` command is executed (typically by the `MOUSERELEASE` keyscript for the same button which executed the `SELECT`) which copies the highlighted text into the paste buffer. Selection is aborted (and the text being selected is un-highlighted) if the PDP-11 sends more data to the screen while selection is in progress.

`SELECTWORD`

Select the word at the current mouse location.

`SELECTLINE`

Select the entire line (including a carriage return character at the end) at the current mouse location.

`SET` *flag* [`FOR` *n*]

Sets a read/write flag. See section A.4 for a list of flag names. If the "`FOR` *n*" modifier is given, it means that the flag is set for the specified non-zero number of data keystrokes, and then automatically clears after the script for the *n*th keystroke is executed. This is used for the prefix keys common on non-English keyboards, and can also be useful for disabled users. Note that the current key (the one whose keyscript contains this "`SET ... FOR` *n*" command) counts from the total unless a `NONDATA` statement is part of its definition.

Example using `SET` to redefine the right-hand `Alt` key as an "acute accent" prefix key, which makes the vowel keys send the ISO Latin-1 codes for the same letters with acute accents when pressed immediately afterwards:

```
DEFINE KEYPRESS RALT = SET FLAG1 FOR 1 : NONDATA
DEFINE KEYPRESS A = IF FLAG1 THEN LETTER CHR$(193) ELSE LETTER 'A' ENDIF
DEFINE KEYPRESS E = IF FLAG1 THEN LETTER CHR$(201) ELSE LETTER 'E' ENDIF
DEFINE KEYPRESS I = IF FLAG1 THEN LETTER CHR$(205) ELSE LETTER 'I' ENDIF
DEFINE KEYPRESS O = IF FLAG1 THEN LETTER CHR$(211) ELSE LETTER 'O' ENDIF
DEFINE KEYPRESS U = IF FLAG1 THEN LETTER CHR$(218) ELSE LETTER 'U' ENDIF
```

`SETUP`

Enters/exits SET-UP mode.

`TICK`

Sends the timer tick number as read by `GETTIME`. Normally this is a 2-digit number, 00–49 for a 50 Hz clock or 00–59 for a 60 Hz clock, but the actual number of digits is selected to fit the maximum possible timer tick number, which is one less than the `SET HERTZ` setting.

`TOGGLE` *flag*

Toggles a read/write flag. See section A.4 for a list of flag names.

`UCMONTH3`

Sends the 3-letter upper case English month abbreviation (`JAN`–`DEC`) as read by `GETTIME`.

`YEAR2`

Sends the 2-digit year (00–99) as read by `GETTIME`.

`YEAR4`

Sends the 4-digit year (1980–2099) as read by `GETTIME`.

A.3 Key names

This section defines the key names used for `DEFINE KEYPRESS`, `DEFINE KEYRELEASE` commands, and `PRESS`, `RELEASE` statements. Keycap descriptions are for US English keyboards and may differ on keyboards designed for other languages. For most of these keyboards the physical layout is close to the US layout so name of the key that would be in the same position on a US keyboard should be used in script language definitions. Keys labeled "EKB only" exist only on the 101-key "Enhanced" keyboard and the 104-key "Windows 95" keyboard. It is not considered an error to bind keyscripts to them even when only an 84-key AT keyboard is present, but keyscripts for keys that are missing will never be executed.

,

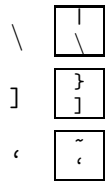
* * key on keypad, or

key if present

,

\-

.	
/	
0–9	Numeric keys (top row of main keyboard)
;	
=	
A–Z	Alphabetic keys
BACKSPACE	Backspace key (top right of main keyboard)
CAPSLOCK	Caps Lock key
CONTEXT	Context Menu key (104-key keyboard only)
DARROW	Down arrow key (EKB only)
DEL	Del (EKB only)
END	End (EKB only)
ENTER	Enter
ESC	Esc
F1–F12	Function keys (F11, F12 are on EKB only)
HOME	Home (EKB only)
INS	Ins (EKB only)
KP0–KP9	Numeric keys on keypad
KPENTER	Enter key on keypad (EKB only)
KPMINUS	- key on keypad
KPPERIOD	. key on keypad
KPPLUS	+ key on keypad
KPSLASH	/ key on keypad (EKB only)
LALT	Left (or only) Alt key
LARROW	Left arrow key (EKB only)
LCTRL	Left (or only) Ctrl key
LSHIFT	Left Shift key
LWIND	Left “Windows” key (104-key keyboard only)
NUMLOCK	Num Lock key
PAUSE	Pause key (EKB only) — N.B. most keyboards send the “release” code for this key immediately after the “press” code, rather than waiting until the user actually releases the key, so it would not be useful to try to redefine this key as a shift key
PGDN	PgDn (EKB only)
PGUP	PgUp (EKB only)
POWER	Power (newer keyboards)
PRSCR	Print Screen key (EKB only)
RALT	Right Alt key (EKB only)
RARROW	Right arrow key (EKB only)
RCTRL	Right Ctrl key (EKB only)
RSHIFT	Right Shift key
RWIND	Right “Windows” key (104-key keyboard only)
SCRLOCK	Scroll Lock key
SLEEP	Sleep (newer keyboards)
SPACE	Space bar
SYSREQ	Sys Req (84-key keyboard only)
TAB	Tab
UARROW	Up arrow key (EKB only)
WAKE	Wake (newer keyboards)
[	



In addition to the above, the following keywords define keys that don't exist on most keyboards, for completeness in case they are useful on special-purpose keyboards:

`KEY00`	Sends scan code 00 hex
`KEY55`	Sends scan code 55 hex
`KEY56`	Sends scan code 56 hex (unmarked key on some keyboards made by Focus)
`KEY59`	Sends scan code 59 hex
`KEY5A`	Sends scan code 5A hex
`KEY5E`	Sends scan code 5E hex (syn. for POWER)
`KEY5F`	Sends scan code 5F hex (syn. for SLEEP)

Mouse button names may be used only in `DEFINE MOUSEPRESS` and `DEFINE MOUSERELEASE` commands:

`LEFT`	Left mouse button
`MIDDLE`	Middle mouse button (if any)
`RIGHT`	Right mouse button
`X1`	Extra button on some mice
`X2`	Extra button on some mice

The double-click, triple-click, and scroll-wheel events are used in `DEFINE MOUSEPRESS` only:

`DOUBLELEFT`	Double-click on left mouse button
`DOUBLEMIDDLE`	Double-click on middle mouse button (if any)
`DOUBLERIGHT`	Double-click on right mouse button
`DOUBLEX1`	Double-click on X1
`DOUBLEX2`	Double-click on X2
`TRIPLELEFT`	Triple-click on left mouse button
`TRIPLEMIDDLE`	Triple-click on middle mouse button (if any)
`TRIPLERIGHT`	Triple-click on right mouse button
`TRIPLEX1`	Triple-click on X1
`TRIPLEX2`	Triple-click on X2
`WHEELDOWN`	Scroll wheel (etc.) down one detent
`WHEELLEFT`	Scroll wheel (etc.) up one detent
`WHEELRIGHT`	Scroll wheel (etc.) left one detent
`WHEELUP`	Scroll wheel (etc.) right one detent

A.4 Flags

The keyboard script language has a number of boolean flags, which may be used in keyscripts and `DEFINE LED` commands. They are broken into two groups: read/write flags, and read-only flags.

A.4.1 Read/write flags

Read/write flags can be tested or modified by keyscripts. Their values may be used in `IF` expressions or `DEFINE LED` commands, or they may be changed using `SET`, `CLEAR`, and `TOGGLE` statements. The descriptions below are only defaults used by E11's initial keyboard definitions, the user is free to redefine them at will.

`CAPS`	Caps Lock state
`EDITBACKUP`	EDT/KED editor direction, maintained by default keyscripts for keypad 4 and 5 (true=BACKUP, false=ADVANCE)
`FLAG`n	User-defined flags (n=1–4), reserved for user keyscripts
`LALT`	Left (or only) Alt key state
`LCTRL`	Left (or only) Ctrl key state
`LSHIFT`	Left Shift key state
`NUM`	Num lock state
`RALT`	Right Alt key state
`RCTRL`	Right Ctrl key state
`RSHIFT`	Right Shift key state
`SCROLL`	Scroll lock state (any change sends XOFF or XON)

A.4.2 Read-only flags

Read-only flags can be tested by keyscripts but not modified. This means they may be used in `IF` expressions or `DEFINE LED` commands, but not in `SET`, `CLEAR` or `TOGGLE` commands. The values are maintained and updated by E11 itself.

`ALT`	OR of `LALT` and `RALT`
`APPKEYPAD`	Applications keypad mode (ESC =)
`CHARSETA`	Character set A (UK) is currently selected
`CHARSETB`	Character set B (US) is currently selected
`CHARSET0`	Character set 0 (graphics) is currently selected
`CHARSET1`	Character set 1 (undefined) is currently selected
`CTRL`	OR of `LCTRL` and `RCTRL`
`CURSORKEY`	Cursor key mode (ESC [?1h)
`EKB`	True: 101-key Enhanced (or 104-key W95) keyboard, false: 84-key AT keyboard
`G0`	G0 character set is selected (SI)
`G1`	G1 character set is selected (SO)
`INSERT`	VT102 "insert" mode is active (ESC [4h)
`L1`	keyboard LED 1 is lit (ESC [1q)
`L2`	keyboard LED 2 is lit (ESC [2q)
`L3`	keyboard LED 3 is lit (ESC [3q)
`L4`	keyboard LED 4 is lit (ESC [4q)
`LOCAL`	Terminal is in local mode
`NEWLINE`	Newline mode (ESC [20h)
`ONLINE`	Terminal is on-line (not in local mode)
`SHIFT`	OR of `LSHIFT` and `RSHIFT`
`TERAK`	Terak keyboard (TK:)
`VT52`	VT52 mode (ESC [?2l)
`WPS`	WPS terminal (\ and `LINE FEED` (`CONTEXT`) keys swapped)

Appendix B

Debugging Features

Ersatz-11 provides a full assortment of debugging commands. These can be useful for PDP-11 program development, and can also be invaluable for troubleshooting configuration problems, or for providing detailed information to D Bit when reporting a problem in Ersatz-11 itself.

Real PDP-11s all provide some form of programmer's console. This can be either a traditional binary "switches and lights" front panel, an octal keypad and LED display, a simple ASCII console emulator program running out of ROM, or the "Micro-ODT" program implemented in microcode in systems based on the LSI-11, DCF11, and DCJ11 chip sets. Regardless of the implementation, the programmer's console provides some way to examine and deposit memory, inspect and modify the general registers and processor status word, and control program execution.

E11 provides all of this functionality, as well as many more features, using the interactive "`E11>`" command prompt, which can be popped up at any time by pressing Shift-Enter. Most of the commands related to program debugging can be abbreviated to one letter, to save typing, and the user can further streamline the debugging process by binding often-used commands to a single keystroke using `DEFINE KEYPRESS` commands.

Debugging commands:	
ASSEMBLE	Assemble PDP-11 code into memory
C= (etc.)	Set condition flag value
CALCULATE	Evaluate an expression (abbreviation = "&")
CM= (etc.)	Set current/previous processor mode
DEPOSIT	Deposit into memory or I/O page registers
DUMP	Dump memory to a file
EXAMINE	Examine memory or I/O page registers
FPREGISTER	Display/change floating point registers
GO	Start program execution
HALT	Halt program execution
INITIALIZE	Initialize CPU (like RESET instruction)
LIST	List disassembled PDP-11 code
LOAD	Load a binary file into memory
LOG	Log disk/tape/Ethernet controller commands to a file
MAP	Translate virtual address to physical address
PRIO=	Set processor priority
PROCEED	Proceed with execution, with an optional breakpoint
PS=	Set processor status word
R0= (etc.)	Set general register value
REGISTER	Display general registers and PSW fields
SET DISPLAY	Set up hardware display register
SET PCLOG	Enable/disable PC logging on each fetch
SET SWITCH	Set up switch register (real or virtual)
SHOW CSR	Display name of any I/O page register
SHOW DISPLAY	Inspect value of display register
SHOW MEMORY	Show E11 memory usage
SHOW MMU	Display MMU maps
SHOW VERSIONS	Show version numbers of E11 and host OS
STEP	Execute one (or several) single program step

B.1 Displaying and modifying memory

Memory may be displayed or modified one word at a time using the EXAMINE and DEPOSIT commands. Both can accept switches that define the virtual address space to use. If no switches are specified, the default is to use the same space as the previous EXAMINE or DEPOSIT command. Any switch used on either command sets the default for both commands.

These commands can also operate on multiple memory words. Normally when only one address is specified, the EXAMINE command will display just one word, but if a starting and ending address is specified, that entire range, no matter how large, is displayed on the terminal. If an EXAMINE command is given with no address whatever, it displays eight words starting at the word following the last EXAMINE command. Multiple words can be entered into memory by simply entering more than one number following the address in a DEPOSIT command. The numbers are entered into consecutive words of memory starting at the specified address. For convenience, these commands may be abbreviated to E and D.

B.2 Assembly and disassembly

The ASSEMBLE and LIST commands display or modify memory in very much the same way as the EXAMINE and DEPOSIT commands, except that they accept and display assembly language source instead of octal data. Both commands accept optional switches to set the virtual address space to use, and if no switches are specified the default is to use the same virtual address space from the previous ASSEMBLE or LIST command.

The ASSEMBLE command starts the assembler at the specified address, or if no address is specified the default is to continue assembly at the next address following the last line assembled by the previous ASSEMBLE command. E11 prompts for each line, giving the address where it will be entered into memory. Entering a blank line (or typing CTRL/C) returns to the E11 command prompt.

The LIST command lists eight lines of code starting at the specified address, or if no address is specified then eight lines of code are disassembled following the last line displayed by the previous LIST command or REGISTER display. Two addresses can be given, to produce a disassembly of all code in that range of addresses.

B.3 Registers

The PDP-11 registers may be displayed at any time using a REGISTER command (R for short). This displays all of the registers and PSW flags at once. Individual registers may be displayed using commands like "& R3". Any value that is displayed by the REGISTER command may be set using the same keywords as is used in the display. For example, if the register dump includes "C=1" and "PM=U" to indicate that the carry flag is set and the previous mode is "user", it is possible to clear the carry flag by typing "C=0", or change the previous mode to "supervisor" by typing "PM=S". And of course the general registers may be changed with commands such as "R3=100", or even "SP=SP+4".

The FP11 floating point processor state may be inspected using the FPREGISTER command. However it is less flexible than the regular REGISTER command, all register values are displayed and set using octal numbers.

The SET PCLOG ON command can be used to log the PC value before each instruction fetch, at a slight speed penalty. The last 64 values may be shown at any time using SHOW PCLOG. This can be very useful for tracing the events leading up to a trap or halt.

B.4 Breakpoints and single-stepping

The PROCEED command takes an optional numeric argument, which is a PC value. PDP-11 instruction execution will halt whenever that address is reached. This is done using address comparison, rather than by depositing anything into memory (regular PDP-11 debuggers do breakpoints by inserting a BPT instruction into memory), which means it works even if the memory contents are overwritten before the breakpoint is reached.

STEP allows proceeding one instruction at a time. If a numeric argument is specified, it gives the number of steps to perform, with a default of one step. This command can be abbreviated to S so that it may be typed quickly. For even greater convenience, a key may be redefined to enter this command with a single keystroke. For example:

```
def key kpplus = 'step'+chr$(13)
```

This will cause a step to be executed every time the keypad + key is pressed.

The GO command starts execution at full speed, with no breakpoints or single stepping. An optional starting address may be given. If it is omitted, execution continues at the current PC value. Unlike some versions of ODT, E11 does not issue an implied INIT pulse with either the GO or PROCEED command. If necessary the system may be initialized, including all emulated devices and bus adapters, using a separate INITIALIZE command.

B.5 Memory mapping

E11 can display the current status of the memory management unit at any time using the SHOW MMU command. There are two optional arguments, the mode (KERNEL, SUPERVISOR, or USER) and the space (INSTRUCTION or DATA). Both may be abbreviated to one letter, and the defaults are KERNEL INSTRUCTION. The display for each page gives the starting virtual address, starting physical address, block limits, access, and the A (accessed) and W (written) dirty bits. Also, the current values of MMR0 through MMR3 are displayed (MMR3 is omitted if the current CPU emulation doesn't include MMR3).

The MAP command may be used to compute a physical address, given a virtual address. It takes the same switches as the EXAMINE and DEPOSIT commands, to give the mode and space parameters for the virtual address. It displays the resulting 22-bit physical address, as if it had been processed by the MMU during a PDP-11 instruction. However, like the EXAMINE and DEPOSIT commands, the MMU's status is not affected by this command, so the A bit will not be modified in this page's PDR, and no MMU abort will occur if the page is marked "no access" or the address is outside of the range of valid blocks in that page.

The SHOW CSR command displays a one-line description of an emulated CSR on the I/O page, given its address. It works only on devices which are currently configured.

B.6 Device logging

Although the controller LOG commands are provided mainly as an aid to reporting Ersatz-11 problems to D Bit, they can be invaluable to users who are debugging device drivers or boot blocks. When logging is enabled for a given disk, tape, or network controller, every command issued to that controller by the PDP-11 is recorded in the log file with a time stamp. Other parameters such as buffer addresses and lengths, unit numbers, disk addresses, and tape record lengths, are recorded too, and for some devices the command's completion status is saved as well. For Ethernet devices, switches on the LOG command line give independent control over logging of host commands, transmitted packets, and received packets.

B.7 Loading and dumping memory

The LOAD and DUMP commands may be used to transfer between PDP-11 memory and files on the host system. An optional series of address ranges may be specified to do scatter/gather transfers. If no addresses are specified, the transfer starts at the beginning of memory and goes until the end of the files (for LOAD) or the end of memory (for DUMP).

B.8 Switch and display registers

The `SET SWITCH` and `SHOW DISPLAY` commands give access to emulated switch and display registers, which work the same way as those on the binary front panels on early PDP-11 models. The switch/display register is located at address `17777570` as long as a `SET CPU SR` command, or some other `SET CPU` *nn* command which includes `SR`, has been issued. This provides a crude one-word I/O register which can be accessed by a program running in kernel mode, for things like displaying checkpoint information during debugging.

Simple hardware can be attached to E11's switch register and display register emulations using `SET` commands. A display register which connects to an LPT port is available from D Bit as a bare PC board.

Appendix C

Installable Plug-ins

Ersatz-11 has a built-in linking loader, invoked by the `INSTALL` command, which allows "plug-in" modules to be integrated with E11 at run time. This makes it possible to implement custom devices and/or instructions using 80x86 assembly language, Watcom C, or Digital Mars C, without requiring a custom version of Ersatz-11 or access to its source code.

A plug-in module is in the 32-bit "portable executable" .DLL format, which is the standard executable file format for Windows NT and Windows 95 and later, and is supported by standard linkers. Ersatz-11 provides no-op stubs for a number of Win32 calls, so that the regular Windows library start-up module supplied with Watcom C or Digital Mars C will run unmodified. The supplied stubs are only enough to start up the C code without errors, but they don't provide Windows system services. In particular, anything which uses `malloc()` will not work (use `GetMemory()` instead).

There is no difference in the file format or command syntax needed to load an instruction emulation plug-in, as compared to a device emulation plug-in. A plug-in's purpose is defined by the calls it makes. Also, there is no need to split multiple device or instruction emulations into separate modules, they can be combined into one.

C.1 Calling conventions

As is traditional with Win32 DLLs, Ersatz-11 plug-in modules must use `__stdcall` calling conventions when calling API entry points, and these conventions are also used when Ersatz-11 is calling user code. These are as follows:

- Caller pushes arguments right to left, before making NEAR call
- Callee pops arguments upon return, using `RET` *n* instruction
- EBX, EBP, ESI, EDI and all segment registers are preserved by callee
- DF is 0 on entry and must be preserved by callee
- Symbol names are case-sensitive but are otherwise used as-is (no underscore prefix or `@`*nn* suffix is added, despite linker-induced illusions to the contrary)
- Return value (if any) is passed in EAX (zero- or sign-extended as needed)

C.2 Entry conditions

After a plug-in module is loaded and linked, a call is made to its entry address, with the following parameters:

```
int __stdcall DllMain(unsigned long hinstDLL,unsigned long fdwReason,void *lpvReserved)
```

This is compatible with the standard Win32 DLL entry point (and this is the name of the user-written routine which the C library startup code will call after its own initialization, with the same parameters).

`hinstDLL` is a unique number assigned when the module is loaded. It has no purpose in E11, but is part of the Win32 library startup so it is included for compatibility.

`fdwReason` is the reason for the call, either 1 (`DLL_PROCESS_ATTACH`) if the library is being loaded, or 0 (`DLL_PROCESS_DETACH`) if it is being unloaded.

`lpvReserved` points at the command line when loading, and contains NULL when unloading. The command line is whatever follows the filename in the `INSTALL` command, if anything, in DOS form (i.e. a length byte followed by a CR-terminated string). This can be useful for passing CSR addresses (etc.) or other configuration information to the installed module. For example, "`INSTALL FOO.DLL CSR=164000`" will result in `lpvReserved` pointing at the following (in E11's own scratch memory, which will be re-used after the initialization routine returns):

```
.BYTE   11.             ;length of string
.ASCII  / CSR=164000/   ;the string itself
.BYTE   15              ;always ends with carriage return
```

`DllMain()` returns 1 (`TRUE`) for success, or 0 (`FALSE`) for failure, in which case E11 will issue an error message.

C.3 Exit conditions

Since the loading of a plug-in module, and whatever calls it makes, are completely unrelated in E11, E11 has no idea what resources have been allocated by a particular module so it doesn't automatically free them when that module exits (e.g. due to a QUIT command). Therefore, each module must keep track of its resources and free them when they are no longer needed. The library shutdown call to `DllMain()` is a good time to release any unneeded resources.

C.4 Building plug-in modules

All C source files should include a `#include ''e11.h''` line at the beginning. The `E11.H` header file and `E11.LIB` import library are available from D Bit.

To build a DLL with Watcom C (available from www.openwatcom.org, runs under MS-DOS or Windows or OS/2), compile and link as follows (e.g. to build FOO.DLL from FOO.C):

```
wcc386 -bt=nt -bd -s foo.c
wlink @foo
```

This requires a `FOO.LNK` linker script as follows:

```
system nt_dll
name foo.dll
file foo
library e11.lib
```

To build a DLL with Digital Mars C (available from www.digitalmars.com, runs under Windows), compile and link as follows (e.g. to build FOO.DLL from FOO.C):

```
dmc -mn -WD foo.c e11.lib kernel32.lib
```

C.5 Entry points

This section defines all of the callable Ersatz-11 entry points. They are grouped roughly by function. Most of these calls may be safely made only from main program level, i.e. *not* from an interrupt service routine, signal handler, or non-mainline thread. Exceptions are noted in the entry point descriptions below.

An include file and import library for Watcom C or Digital Mars C are available from D Bit. Defined data types are as follows:

`E11HANDLE` is a 32-bit token used by E11 internally.
`word` is an unsigned 16-bit value.
`dword` is an unsigned 32-bit value.

Pointers are normally 32-bit flat addresses. DLLs are considered to be trusted, so E11 does not check parameter values and crashes are possible if bad numbers are passed.

C.5.1 Ersatz-11 environment

This section describes calls which obtain information about the environment where the plug-in module is running.

`unsigned long E11Version(void)`

Returns the Ersatz-11 version number, as follows:

```
MAJOR*256.+MINOR
```

MAJOR is the major version number as an integer, and MINOR is the minor version number in hundredths (0–99).

`void *GetItem(const char *itemname)`

Gets a pointer to a constant data structure or string, which corresponds to the supplied .ASCIZ item name. If the item is undefined, then NULL is returned. This allows checking for arbitrary E11 features which may be present in particular versions, without needing specific knowledge of ranges of Ersatz-11 versions.

C.5.2 I/O device emulation

The most likely purpose for a plug-in module is to emulate a peripheral device. In order to do this, it must be able to intercept reads and writes to its I/O page registers, and must be able to interrupt the emulated PDP-11 and/or perform DMA to and from PDP-11 memory. The next few calls accomplish these functions.

```
E11HANDLE GetCSRBlock(dword first,dword count,word (*dati)(),void (*dato)(),
        void (*init)())
```

Allocates a block of control/status register locations on the I/O page, to be emulated by this module. The return value is zero on failure, otherwise it's a handle which may later be passed to `RetCSRBlock()` to release the block of addresses. `first` is the absolute address of the first CSR to allocate, and is represented as a 22-bit even number, even if the current CPU emulation is set for a smaller address space. `count` is the count of registers, i.e. the number of words of I/O space to allocate starting at that address. `dati`, `dato`, and `init` are pointers to functions which E11 will call according to what the PDP-11 code does:

```
word __stdcall dati(dword addr)
```

Called whenever the PDP-11, or console `EXAMINE` command etc., reads a byte or word on the I/O page which is within the range passed to `GetCSRBlock()`. This is equivalent to a Unibus "DATI" bus cycle. PDP-11 busses do not distinguish between byte and word read cycles, a word is always read and if it's a byte instruction then the CPU chooses the proper byte out of that word. `addr` is the absolute 22-bit address of the I/O page location to be read, and the function's return value is the 16-bit word to be passed back to the PDP-11.

```
void __stdcall dato(dword addr,dword value,dword datob)
```

As above, but called when a byte or word is being written to an I/O page register in the range covered by the `GetCSRBlock()` call. This is equivalent to a Unibus "DATO" or "DATOB" bus cycle. `addr` is the absolute 22-bit I/O page address as above. `value` is the 16-bit word to be written, or if it's a byte write, it's two side-by-side copies of the 8-bit byte being written. `datob` distinguishes between word and byte writes, 0 means word (DATO), 1 means byte (DATOB).

```
void __stdcall init(dword addr)
```

Called on every `RESET` instruction, or on console `INITIALIZE` commands etc. This is equivalent to a Unibus "INIT" pulse. The device emulation code should perform whatever initialization would be appropriate for a bus reset. `addr` is the base 22-bit address that was passed to `GetCSRBlock()`, and is supplied in case the same handler routine is used for more than one device, so that it can tell them apart.

```
void RetCSRBlock(E11HANDLE handle)
```

Returns a block of I/O page CSR registers, which had previously been allocated using `GetCSRBlock()`. This is normally done as part of the cleanup in the module's `DllMain()` exit handling. Future accesses to the I/O page addresses covered by the `GetCSRBlock()` call will cause emulated bus timeouts.

E11HANDLE GetIntQel(dword level,dword rank,dword vec)

Allocates an interrupt queue element. A module which needs to deliver emulated interrupts to the PDP-11 must allocate one interrupt queue element for every possible interrupt that can be outstanding at one time. This normally means one queue element for each interrupt vector that the device uses. This function returns zero on failure, otherwise the return value is the queue element's handle, which is a number used to identify the queue element in other calls to E11.

`level` is the interrupt priority level, which must be in the range 4–7. This corresponds to the Unibus BR and BG lines (or their Q-bus equivalents), and is the same as the priority that would be set using a priority jumper plug on a typical Unibus peripheral card.

`rank` is the daisy chain rank within a given priority level, and indicates the device's distance from the CPU on this priority level. Since the emulator has no physical daisy chain, it's generally not possible to know what other devices this one should go between, so the daisy chain rank is just a rough guess. The value 0 is reserved for the PIRQ feature that's built into some CPU models, and E11 generally uses 1 for the 50/60 Hz clock and the console SLU ports, since in most systems these are physically located on the CPU card, or immediately next to the CPU. So most devices will use values 2 and up. If two devices interrupt at the same priority level and with the same daisy chain rank, E11's policy is to acknowledge them in the order that they occurred.

Finally, `vec` is the vector address through which the interrupt will be taken once it is acknowledged. It must be a multiple of four. The vector need not be valid except when an interrupt has actually been enqueued using `EnqueueInt()`, so if the `EnqueueInt()` completion routine will set the vector at bus grant time, a junk value such as -1 may be used here.

void RetIntQel(E11HANDLE handle)

Returns an interrupt queue element that had been obtained earlier using `GetIntQel()`. This call is normally made as part of the `DllMain()` exit processing. If an interrupt is enqueued using this queue element, it is dequeued before the element is freed.

void EnqueueInt(E11HANDLE handle,int (*crtn)(dword),dword parm)

Enqueues an interrupt request on a previously allocated interrupt queue element. This is equivalent to a Unibus device asserting its "BR" line and waiting for service. The interrupt is only enqueued, and has not yet begun processing on return, because that can only happen when the emulated PDP-11 is between instructions. Note that like most E11 entry points, this one may be called only from main program level, not from a hardware interrupt service routine or signal handler. The `EnqueueFork()` call provides access to E11's internal "fork" queue, which allows scheduling a call in the near future to a user subroutine at main program level, from anywhere. This call may be used in an interrupt service routine or signal handler to schedule a call to a separate user-supplied routine which makes the `EnqueueInt()` call.

Simple devices can simply pass NULL as the `crtn` parameter, and any value for the `parm` parameter. In this case the interrupt will quietly occur on its own whenever the PDP-11 lowers its priority and begins interrupt service, and the vector address that was set in the `GetIntQel()` call will be used, unless it is canceled by a `DequeueInt()` call before then.

Devices which need to be informed when an interrupt is actually being serviced, and/or need to wait until the last moment to choose an interrupt vector, should pass a function pointer as the `crtn` parameter. This is a completion routine, which is called like this:

```
int __stdcall crtn(dword parm)
```

This routine is called just as the emulated PDP-11 is acknowledging the interrupt and preparing to fetch the interrupt service routine's address from the vector. `parm` is the same value that was passed to `EnqueueInt()`. It may be any 32-bit value and is there so that the same completion routine may be used for more than one device. The routine should do whatever processing its emulated device would do at bus grant time. Its return value is the actual vector address to interrupt through (which need not be the same as the value passed to `GetIntQel()`), or -1 if the interrupt should not be taken after all (a Unibus "passive release").

Very few devices need this routine. An example would be certain models of the 50/60 Hz line clock, which clear the "monitor" flag in bit 7 of the CSR whenever the interrupt request is granted. If a NULL pointer is passed instead of a completion routine address, E11 will just interrupt as usual using the vector address that was already set.

```
void DequeueInt(E11HANDLE handle)
```

Dequeues an interrupt request which was scheduled using the `EnqueueInt()` call. This is generally done on bus resets, or any time the emulated device's status is changed so that a previously enqueued interrupt will not happen after all. `handle` is the handle of the interrupt queue element to dequeue, as returned from `GetIntQel()`. It is perfectly safe to call this routine if no interrupt was actually enqueued, in this case it will simply return without doing anything. However the `handle` parameter must be valid, since unpredictable behavior will result if it is not.

```
long AbsTransfer(dword func,dword pdp11addr,void *x86addr,dword len)
```

```
long MapTransfer(dword func,dword pdp11addr,void *x86addr,dword len)
```

Performs DMA between 80x86 memory and emulated PDP-11 memory. `func` gives the direction of the transfer, either `TOPDP` to transfer from the host to the PDP-11, `TOHOST` to transfer from the PDP-11 to the host, or `COMPARE` to compare the two. `pdp11addr` gives the PDP-11 buffer address, either an 18-bit Unibus address (for `MapTransfer()`, which goes through the Unibus map if it is present and enabled), or an absolute 22-bit address (for `AbsTransfer()`, which uses absolute addressing like Q22-bus or the RH70). `x86addr` is the 80x86 buffer address. `len` is the length of the transfer. The return value is zero on success, or the number of bytes *not* transferred (if stopped due to a bus timeout), or the two's complement of this number (if stopped due to a compare mismatch).

C.5.3 PDP-11 instruction emulation

A plug-in module may be used to add custom instructions to the PDP-11 architecture, or provide modified versions of existing ones. This is similar to what was possible using the hardware user microcode options on the LSI-11 and PDP-11/60 machines, but it is much more powerful since the code doing the emulation has access to the entire host computer and operating system, rather than just a PDP-11 micro-machine.

```
E11HANDLE GetOpcode(dword first,dword count,void (*exec)(),void (*init)())
```

Allocates a block of PDP-11 opcodes to be emulated by this module, instead of by Ersatz-11 itself. The return value is zero on failure, otherwise it's a unique handle which may later be passed to `RetOpcode()` when the instruction handler is unloaded. If the range of opcodes conflicts with existing PDP-11 instructions, or other loaded plug-ins, whoever requested each opcode last will be the one called when it gets executed by the PDP-11.

`first` is the first opcode value to be intercepted and passed to this handler. `count` is the number of opcodes to be intercepted, starting with that value. `exec` and `init` are subroutines which E11 will call when appropriate, as follows:

```
void __stdcall exec(dword opcode)
```

This routine is called by E11 any time an opcode is executed which is in the range from `first` to `first`+`count`-1. `opcode` is the actual opcode used, and may be used for the handler's internal dispatch table, `switch()` statement, etc. This routine does whatever processing is required to execute the instruction, and uses other calls (defined below) to read and write PDP-11 registers and memory space.

```
void __stdcall init(void)
```

This routine is called any time the PDP-11 is initialized, through a `RESET` instruction, `INITIALIZE` command etc.

`void RetOpcode(E11HANDLE handle)`

Returns a block of PDP-11 opcodes, previously allocated using `GetOpcode()`. This call is a normal part of `DllMain()` exit processing.

`word GetReg(dword regnum)`

Reads the value of one of the eight PDP-11 registers, in the current register set. `regnum` gives the register value, 0–5 for R0–R5, 6 for the SP, and 7 for the PC. The return value is the 16-bit register value.

`void SetReg(dword regnum,dword value)`

Sets the value of a PDP-11 register. `regnum` is the register number (0–7, the same as for `GetReg()`), and `value` has the value to store there in its low 16 bits.

`dword GetPSW(void)`

Reads the zero-extended value of the processor status word.

`void SetPSW(dword value)`

Sets the value of the processor status word to `value`.

`long Peek(dword space,dword pdp11addr)`

Reads a word from a PDP-11 virtual address space. `space` selects which space to use, and is one of the following:

0	KD	kernel data space
1	KI	kernel instruction space
2	SD	supervisor data space
3	SI	supervisor instruction space
6	UD	user data space
7	UI	user instruction space
8	D	current data space
9	I	current instruction space
10	PD	previous data space
11	PI	previous instruction space

`pdp11addr` is the 16-bit virtual address to read within that space. On success, the return value is the data word, in the range 0–177777 octal. If the read fails due to an odd address, MMU error, or bus timeout, -1 is returned. Note that the return value is a signed 32-bit number, so that the -1 error indication can be distinguished from a valid data value of 177777 octal.

```
long PeekB(dword space,dword pdp11addr)
```

Byte version of `Peek()`, reads a byte from a PDP-11 virtual address space. Return value is the 8-bit byte sign-extended to a 32-bit number, or else -1 the in case of an error.

```
int Poke(dword space,dword pdp11addr,dword data)
```

Writes a word into a PDP-11 virtual address space. `space` selects which space (see table above), `pdp11addr` is the 16-bit virtual address in that space, and the low 16 bits of `data` are the word to write to that address. The return value is 0 on success, or -1 on failure.

```
int PokeB(dword space,dword pdp11addr,dword data)
```

Writes a byte into a PDP-11 virtual address space. The parameters and return value are the same as for `Poke()`, except that only the low 8 bits of the `data` parameter are used.

```
long PeekCD(dword pdp11addr)
```

```
long PeekBCD(dword pdp11addr)
```

```
int PokeCD(dword pdp11addr,dword data)
```

```
int PokeBCD(dword pdp11addr,dword data)
```

Special versions of `Peek()`, `PeekB()`, `Poke()`, and `PokeB()`, which access the current data space. Execution is slightly faster than the equivalent `Peek(D,...)` (etc.) calls.

```
long PeekPhys(dword pdp11addr)
```

```
long PeekBPhys(dword pdp11addr)
```

```
int PokePhys(dword pdp11addr,word data)
```

```
int PokeBPhys(dword pdp11addr,word data)
```

Special versions of `Peek()`, `PeekB()`, `Poke()`, and `PokeB()`, which bypass the MMU to access 22-bit physical address space.

C.5.4 PC memory management

```
void *GetMemory(dword size)
```

Allocates a block of PC memory. `size` is the size of the requested region in bytes. If successful, returns a pointer to the block of memory. Returns zero (`NULL`) on failure.

```
void RetMemory(void *addr)
```

Frees a block of PC memory, previously allocated by `GetMemory()`.

C.5.5 Fork queue

There are often cases where an interrupt service routine or signal handler, which is entered asynchronously, needs to switch to main program level. This may be because it needs to call code which is non-reentrant, such as the majority of E11 entry points, or it needs to perform processing which would take too long to be done at interrupt level. E11 does this by enqueueing requests for callbacks, and then processing them at "fork level", which is what the main program switches to whenever E11 is between PDP-11 instructions and there are items in the "fork queue". Callbacks are made serially (one at a time) until the fork queue is empty. Many PDP-11 operating systems have a similar concept, so this may be familiar.

```
E11HANDLE GetForkQel(void)
```

Allocates a queue element which can be used to enqueue requests for callbacks at fork level. One queue element is required for every possible request that can be outstanding at one time. The return value is a non-zero handle to the queue element on success, or zero on failure.

```
void RetForkQel(E11HANDLE handle)
```

Frees a fork queue element that was obtained earlier from `GetForkQel()`. If a request is currently enqueued, it is dequeued before the queue element is flushed. This routine would normally be called during the module's

`DllMain()` exit processing.

`void EnqueueFork(E11HANDLE handle,void (*crtn)(dword),dword parm)`

Enqueues a request for a callback at fork level. `handle` is the queue element handle returned from `GetForkQel()`, `crtn` is a pointer to the completion routine to call at fork level, and `parm` is an arbitrary 32-bit parameter which will be passed to the completion routine. `EnqueueFork()` is unusual in that it may be safely called from an interrupt service routine or signal handler.

NOTE: on DOS systems, this routine must be called with interrupts disabled, and it returns with interrupts still disabled.

The completion routine is called in the very near future, before the next PDP-11 instruction is fetched, as follows:

```
void __stdcall crtn(dword parm)
```

`parm` is the same value that was passed to the `EnqueueFork()` call, and is for user-defined purposes, for example it may be a pointer to per-instance data so that the same fork completion routine may be used for several different devices. When the completion routine is called, E11 is running at main program level, and all entry points are safe to call.

`void DequeueFork(E11HANDLE handle)`

Dequeues the previously queued fork request, if any, which was made using the specified `handle`. If no request had been made, this call simply returns without doing anything.

C.5.6 PC hardware access

On DOS systems, it is often necessary or desirable to program hardware devices directly, instead of using system calls to access them. On a system running in protected mode, user programs must make arrangements with the protected mode supervisor in order to access memory-mapped devices, or handle hardware interrupts. These calls accomplish this, and they should be used instead of the equivalent DPMI calls, in case E11 is running stand-alone (without a DPMI server) under its own built-in protected mode supervisor, because in this case the INT 31h calls will not work.

`void GetHWIntVec(dword irq,word *sel,dword *offs)`

Retrieves the current value of a hardware interrupt vector, as a 16:32 FAR pointer. `irq` is the IRQ number, 0–15 (note that this is *not* the same as the INT vector number, since the INT numbers used depend on how the supervisor has programmed the 8259A interrupt control units). `sel` is a pointer to a 16-bit word where the vector's current code selector will be stord, and `offs` is a pointer to a 32-bit doubleword where the current offset will be stored.

void SetHWIntVec(dword irq,dword sel,dword offs)

Sets a hardware interrupt vector to point at the given 16:32 FAR code address. `irq` is the IRQ number, 0–15 (see above), `sel` is the new 16-bit code selector to use, and `offs` is the new 32-bit offset to use. Upon a hardware interrupt, this interrupt service routine is entered with a FAR interrupt stack frame, so after interrupt service is complete it should return as follows:

```
STI                     ;re-enable interrupts
IRETD                   ;return
```

The `STI` instruction may seem redundant (because the `IRETD` will already restore the interrupt flag value off of the stack, which must have been 1 or the interrupt wouldn't have occurred), but it is necessary in case the interrupt handler is running in ring 3 under a DPMI server. In this case the `IRETD` instruction has insufficient privilege to modify the interrupt flag, but this does not result in a trap to the supervisor. So the (virtual) interrupt flag remains clear and interrupts are still disabled. However the `STI` instruction does trap to the supervisor so that it can be emulated, and the supervisor will set the (virtual) interrupt enable flag.

On DPMI systems that run at ring 0, and on E11's built-in supervisor (which runs at ring 0 most of the time), the `STI` is harmless, since all it does is set the IF flag ahead of time. There is no danger of stack overflow due to the interrupt routine recursing, because `STI` wouldn't actually set IF until after the next instruction executes, and since that's the `IRETD` the routine has already been exited by that time.

void *GetPhysWind(dword base,dword size)

Allocates an address window to a memory-mapped device. Since protected mode systems normally run with paging enabled, it is generally not safe to assume a 1:1 relationship exists between virtual and physical addresses. The exception is devices located in the low 1 MB of the memory space. This area is identity-mapped so there is no need to map a window to devices located there, using any flat pointer is sufficient. If you call `GetPhysWind()` with a base address below 1 MB, it will simply return the same address.

`base` is the 32-bit physical base address of the device, and `size` is the size of the window in bytes. The return value is the non-zero flat 32-bit base virtual address of the window on success, or zero (`NULL`) on failure. Once mapped, this window may be used like any other block of memory.

void RetPhysWind(void *addr)

Frees a physical address window that was obtained earlier with `GetPhysWind()`. `addr` is the flat 32-bit virtual address returned from `GetPhysWind()`.

Appendix D

TCP/IP Network Subsystem

Ersatz-11 includes its own simple TCP/IP networking layer, which must be enabled before the `TELNET:`, `TELSINGLE:`, `TELCLIENT:`, or `UDP:` devices will work. It uses the standard E11 Ethernet device drivers that are described in chapter 7.

In the most common case, there is one Ethernet port and it's started as follows:

```
net start ether-0 dhcp eth0:
```

"`ether-0`" is the networking layer's name for the first Ethernet interface, and "`eth0:`" is the nickname for the first (or only) Ethernet port that E11 is able to auto-detect. The "`dhcp`" keyword means that Ersatz-11 will contact a DHCP server over the network to obtain an IP address, net mask, and default route. This takes a few seconds. Any outgoing `TELCLIENT:` connections will be deferred until an interface is up which has a route to the destination.

If there is no DHCP server available, a command like this must be used:

```
net start ether-0 10.2.0.6 /mask:255.0.0.0 eth0:
```

There is currently no way to add routes manually, so in this case communication will be limited to the local network segment. There is also no working loopback device. These issues will be addressed in future versions of Ersatz-11.

Network commands (subject to change in future versions):

`NET START ETHER-`*n* `DHCP` *pcdev*:
`NET START ETHER-`*n* *a*`.`*b*`.`*c*`.`*d* [`/MASK:w.`*x*`.`*y*`.`*z*] *pcdev*:

Starts up an Ethernet interface for use with the TCP/IP stack. The logical interface names start at `ETHER-0`. The IP address and netmask may be specified explicitly, or if "`DHCP`" appears instead, E11 will contact a DHCP server to get this interface's address information.

`NET SHOW KNOWN LINES`

Lists all currently defined TCP/IP lines.

`NET SHOW LINE ETHER-`*n*

Shows information about the specified line, including DHCP lease status.

`NET SHOW ROUTES`

Shows the routing table.

Appendix E

Microcomputers

Ersatz-11 can be configured to emulate the following PDP-11-based microcomputers:

E.1 PDT-11/130

The PDT-11/130 is a microcomputer based on the LSI-11 chipset, built into a modified VT100 terminal with a dual TU58 cartridge tape drive below the screen. It supports up to 60 KB of memory, which is unusual for a system with no MMU. It runs RT-11 and accesses the TU58 tape using the PD.SYS device handler, which relies on code in ROM to do the actual I/O. D Bit's own reimplementation of this ROM is included as PDT130.PDP. Sample `E11.INI`:

```
set cpu pdt11
load /rom pdt130 170010
mount dd0: drive0.dsk
mount dd1: drive1.dsk
assign pt: dd:
boot pt0: /rt11
```

E.2 PDT-11/150

The PDT-11/150 is a microcomputer based on the LSI-11 chipset. It has no expansion bus, and uses a pair of 8085A processors to simulate the approximate equivalent of a small PDP-11/03 configuration, but it could be built more cheaply and was sold as a "smart" terminal system for data entry, etc. It uses RX01 drives but instead of an RXV11 controller (which would have required a Q-bus) it has a WD1771 floppy controller chip, which one of the 8085As used to simulate an almost-RXV11-like interface called the RXT11. Like the PDT-11/130, it runs RT-11, again using the PD.SYS device handler with help from code in ROM, which D Bit has reimplemented and is included as PDT150.PDP. Also like the PDT-11/130, it supports 60 KB of memory. Sample `E11.INI`:

```
set cpu pdt11
load /rom pdt150 170010
mount pd0: drive0.dsk
```

```
mount pd1: drive1.dsk
boot pd0: /rt11
```

E.3 Terak 8510/a

The Terak 8510/a is a desktop microcomputer with a DEC LSI-11 processor and custom Q-bus cards for everything else. It was produced in the late 1970s and early 1980s. Instead of using a separate console terminal, it has an ASCII keyboard and a video display which can simultaneously display monochrome graphics at 320x240 pixels and text at 80x24 characters, using a soft (reprogrammable) character set. It runs a customized version of RT-11, or the UCSD p-System, or mini-UNIX. E11's Terak 8510/a emulation is new in V6.1 and is likely to have rough edges — please report any bugs.

Sample Terak `E11.INI`:

```
set cpu 03 eis fis
; TK: takes over 177560, so move TT0: out of the way
set tt0: csr=177270
; graphics screen on CON2: (E11 console remains on CON1:)
assign tk: con2:
define key uarrow = chr$(26)
define key larrow = chr$(23)
define key rarrow = chr$(11)
define key darrow = chr$(12)
; some boot blocks check ROM signature to identify controller
load /rom null: 173000:173003
mou qx0: drive0.vol /sector
mou qx1: drive1.vol /sector
; switch to CON2:
primary 2
boot qx0:
```

Appendix F

PDP-11/74 and PDP-11/45 Multiprocessing (EXPERIMENTAL/UNSUPPORTED)

In the late 1970s, DEC built prototype PDP-11 systems which had several modified PDP-11/70 CPUs ("PDP-11/74s") attached to a shared memory to form one large system, and extended RSX-11M to support these machines (this project led to RSX-11M-PLUS). Also, the earlier PDP-11/45 had a limited ability to share its memory with another processor. Ersatz-11 attempts to emulate these multiprocessor machines, however this feature is completely unsupported. D Bit is happy to accept comments and problem reports about E11's multiprocessing features but makes no commitment to act on them. These features are provided for experimental uses only and are not guaranteed to work reliably, or at all.

The vestigial PDP-11/74 code that's still present in RSX-11M-PLUS was written for DEC's internal testing only, and is absolutely, completely unsupported by Mentec, HP, Compaq, or DEC. Please do not contact them about anything having to do with PDP-11 multiprocessing. The RSX multiprocessing code and documentation are there only because there was never any reason to rip them out, but multiprocessing was never officially supported.

A PDP-11/74 multiprocessor system consists of the following:

- 2–4 PDP-11/74 CPUs
- one or more MKA11 shared memory boxes
- DIP11A IIST (interprocessor interrupt and sanity timer) device
- console terminal for each CPU
- peripherals as usual

Below is a simple multiprocessor `E11.INI` file.

```
;
; Get decent response even w/o enough host CPUs
;
set idle release
```

```
;
; Set PDP-11/74 CPU model
;
set cpu 74
;
; Set number of emulated CPUs (changes prompt to CPA>)
;
set cpus=2
;
; Set up console for CPB
;
set tt1: bus=cpb
assign tt1: con2:
;
; Set up IIST ports (using default BUS settings of II0 = CPA, II1 = CPB, ...)
;
assign ii0-1:
;
; Mount disk and tape units
;
mount du0: rsx11mp.dsk
mount mu0: dump.tap
boot du0:
```

F.1 CPUs and console terminals

The `SET CPU 74` and `SET CPUS=`*n* commands are used to set up the processors themselves. You must use both commands, in either order. A `SET CPU 74` command alone will just give you a single PDP-11/74 CPU. The `SET CPUS=`*n* command (*n* is from 1 to 4) changes the number of CPUs in the system. When you add CPUs, the new ones come up halted.

Unlike CPA (the main CPU that E11 starts with), the new CPUs do not get a console terminal set up for them by default, so you must create one for each CPU after CPA. Use a `SET TT`*n*`: BUS=`*x* command to tell E11 that the DL11 will be on CP*x*'s bus, and then use an `ASSIGN TT`*n*`:` command to attach it to a terminal device. As long as it's the lowest-numbered `TT:` device on that CPU's bus, it will use the default console terminal addresses of CSR=17777560 and VECTOR=60, so there will be no need to set those.

Whenever E11 is emulating more than one CPU, the "`E11>`" prompt changes to the name of whichever CPU is operated upon by the execution/debugging commands. Initially this is "`CPA>`", but you can change it by typing the name of the CPU you want (e.g. CPB etc.). Any command which works on the CPU itself is affected by this. That includes EXAMINE/DEPOSIT/LIST, REGISTER, GO, HALT, INITIALIZE, STEP, etc. ASSIGN/MOUNT/SET commands (which add, remove, or configure peripherals) are not affected by the debugger focus, and may be issued at any time. BOOT commands always apply to the CPU that owns the device being booted (according to its SET ... BUS=x setting).

F.2 Busses

Each PDP-11/74 processor has its own Unibus. E11 needs to know which bus each device is on, so most devices have a `SET` *ddcu*`: BUS=`*x* command, which sets that controller to be on CP*x*'s bus. This command must be issued before the command that creates the device. RSX has a corresponding parameter for each device, called the "URM" or Unibus Run Mask. It's expressed variously as an octal number (which represents a binary bitmap, with bit 0 = CPA, bit 1 = CPB, etc.) or as the name of the CPU (e.g. CPA, CPB, etc.). E11 will accept either notation. The fact that RSX always uses "Unibus" in its nomenclature is simply because the PDP-11/74 is a Unibus machine. As far as E11 is concerned, they could just as easily be Q-busses.

Most devices are on bus A by default. The exceptions to this rule are the KW11L line clock and the DIP11A IIST device. There's one KW11L per CPU and it's always on its host CPU's bus, and DIP11A IISTs are useful only in a multiprocessing system so they default to II0: = CPA, II1: = CPB, ... since that's how most users will use them. To avoid causing confusion to users who aren't using the multiprocessor feature, the bus is not shown by `SHOW` commands unless a `SET CPUS=2` (or higher) command is in effect, or the bus is other than `A`. The default CSR/vector values are assigned on a per-bus basis, so the first device of a given type on a given bus always gets the first default CSR/vector values, even if it's not the first device of that type in the entire system. In particular, the DIP11A IIST devices typically all use the same CSR/vector address, but each one is on a different bus. You can always override a device's CSR/vector values with a `SET` command.

F.3 II: — DIP11A interprocessor interrupt and sanity timer

Command syntax:

`ASSIGN II`*n*`:`

Special switches: none

The DIP11A IIST device is the device used by CPUs in a multiprocessor system to interrupt and/or boot other CPUs, and also to inform the rest of the system when one of the CPUs has crashed. It uses a serial bus with an M8717 interface card in each processor. Since the system uses one common memory for all CPUs, there's no need for the IIST to be very complicated, it just makes other CPUs interrupt and it's up to the operating system to set up its internal tables to show what the interrupts mean. RSX does this by setting bits in a CPU's $MPTAB slot. The bit values are defined in [11,10]MPTBL.MAC.

The RSX $IIWAK routine (in [11,10]IISRV.MAC) uses a software polling loop to wait until the target CPU(s) have accepted their interrupt(s), and returns an error mask if they don't all respond in time. A limit of 64 K loop iterations was generous on real hardware, where all CPUs are running continuously at the same speed (and the IIST is a BR6 device so its interrupts are usually serviced immediately), but it can cause problems running under emulation on a multitasking host operating system where threads can pause for many milliseconds at a time, any time there are at least N+1 active threads on a PC with N CPUs.

E11's workaround is to start counting PDP-11 instructions executed after a CPU sends interrupt(s) to other CPU(s). Once the interrupting CPU has executed N instructions, it pauses its own execution (if necessary) until all the CPUs it's interrupting have also executed N instructions. On a quiet SMP PC with one real 80x86 CPU for each emulated PDP-11 CPU and no active tasks besides E11, this pause will normally be short or nonexistent. But this method means that $IIWAK will always succeed, even on a heavily loaded single-CPU host PC. The default value of *n* has worked in testing, but if necessary it may be changed with the `SET DELAY DIP11A 0=`*n* command.

SET II: controller parameters:	
BUS=*x*	set home bus segment to CP*x*
CSR=*nnnnnn*	set CSR address to *nnnnnn* octal
PRIORITY=*n*	set interrupt priority to *n* (4–7)
PRIORITY=DEFAULT	set interrupt priority to default (BR6 for Unibus, BIRQ6 for Q-bus)
VECTOR=*nnn*	set vector address to *nnn* octal

F.4 Configuring RSX-11M-PLUS for multiprocessing

These instructions are for RSX-11M-PLUS V4.6. Other versions are likely to have differences, which you'll have to figure out. As mentioned at the beginning of this chapter, this feature is unofficial and is not supported in any way by Mentec or any of DEC's incarnations. Not only is it unsupported, but there has never been much hardware to test it on, so the configuration tends to be fragile, and you need to make careful choices and you may need to solve some problems with the automatically-generated build scripts. If at all possible, you should probably try to install completely from scratch (from a Mentec distribution tape), rather than trying to merge multiprocessor support into an existing system. The fewer parameters you change at once, the better.

The first thing you need to do is to edit [200,200]SGNPREFIX.CMD, comment out `.SETF $M$PRO` (by putting "`.;`" before it) and uncomment `.SETT $M$PRO`, before doing your `@SYSGEN`. When you've done this, suddenly SYSGEN will know all about multiprocessor systems and will ask you many more questions when you run it. The important answers are:

- Number of CPUs (obviously)
- IIST — the default CSR/vector addresses are OK, but see below
- MK11 (MKA11) memory boxes — you must define at least one, even though E11 doesn't specifically emulate them (E11's memory is non-relocatable and always on line)
- Don't specify "XX:" as your crash device, or you'll get an undefined global
- Don't include XDT

You can define other peripherals as usual. It will include a lot of RH70 Massbus adapters without asking you, which is fine. It's up to you whether you put devices on them or use some other kind of disks/tapes. Be careful when including TMSCP tapes ("MU:"), since RSX's default vector for a TMSCP controller is 260, which is the same as the IIST so you should set one of them to something else. MU: is easier to move since its vector is set in software so you won't need to add a `SET MU:` command to your E11.INI file. Similarly, the default CSR and vector for the TA11/TU60 DECcassette ("CT:") are both the same as the IIST, and so is the priority so this is probably not a coincidence (the TU60 wasn't very popular and was mainly used on low-end systems so it may have been a sensible device from which to borrow the CSR/vector). So you'll have to move one or the other if you need CT:.

The rest of the build/save/bootstrap process is the same as always, unless you have errors to work out. Once you have a bootable disk, just boot it the same as on a single-CPU system. Then use the CON ONLINE CPB (etc.) command to boot the other CPU(s) and bring them on line — they aren't included in a CON ONLINE ALL command. It normally takes a little over four seconds to bring a new CPU up, because HRC's boot code includes a 4-second delay between booting the CPU and interrupting it to see if it has come up successfully. The new CPU's console terminal is brought online implicitly when the CPU is started, so there's no need for CON ONLINE YLB (etc.) commands to wake up the consoles.

Ersatz-11's multi-processing support is fragile, and it is easy to crash E11 by doing the wrong things, or by doing the right things in the wrong order. Most emulated devices try to be multiprocessing-compatible, but only a few of

the physical device drivers have multiprocessing support. They are: disk image files, tape image files, RAM disks, RAM tapes, CON: terminal sessions, Linux character devices, and Win32 COM: devices. Anything else is likely to malfunction when attached to a processor other than CPA.

Currently it is important that a processor be created (with `SET CPUS=`*n*) *before* any devices are attached to it with `MOUNT` or `ASSIGN` commands. The `SET ... BUS=`*x* command that sets the bus must also come before the `MOUNT` or `ASSIGN`. This applies even to TU58 controllers, which are not actually attached to a bus but must handle events on the same CPU as the DL11 to which they are connected. If this requirement is not satisfied, data structures may be corrupted.

There are other known bugs: currently it appears to be impossible to bring more than three CPUs online under E11 — CON gives an "offline" error on whichever one you do last, no matter which one it is (not just CPD). This is presumably because of a bug in E11. Also, sometimes a CPU will halt for no apparent reason. D Bit makes no commitment to fix these or any other multiprocessing-specific bugs, but would be very interested in hearing any input on what might be going wrong.

F.5 Multiple PDP-11s with non-shared memory

There are a few scenarios where it may be useful to have multiple PDP-11 CPUs which are completely separate. This is generally no different from running separate instances of E11 under a multi-tasking host OS, except on DOS where there can be only one instance. Creating multiple separate PDP-11s is done the same way as creating a mP PDP-11/74 system, except that the SET CPU NOSHAREDMEM command must be used to give each CPU private memory, and since there are no IISTs each processor must be booted individually.

Here's a multiprocessor `E11.INI` file for separate CPUs:

```
;
; Set PDP-11/45 CPU model (all must be the same) with private memory
;
set cpu 45 nosharedmem
;
; Set number of emulated CPUs (changes prompt to CPA>)
;
set cpus=2
;
; Set up console TTY for CPB
;
set tt1: bus=b
assign tt1: con2:
;
; Mount disks (move DKB: controller to CPB)
;
set dkb: bus=b
mount dka0: rk05a.dsk
mount dkb0: rk05b.dsk
;
; Boot CPUs (do CPA last since it will take the CTY away from E11.INI)
;
boot dkb0:
boot dka0:
```

F.6 DPDISK: — Dual-ported disk

This pseudo-device makes any block device appear to be dual-ported, so that it may be mounted on two different controllers (typically an RK611, RH11, or RH70, since they supported real dual-ported drives, but this isn't a requirement in E11), normally attached to different CPUs of a multi-processor system. Normal usage is as follows:

```
mount dpdiska: rsx.dsk
mount dba0: dpdiska0:
set dbb: bus=b
mount dbb0: dpdiska1:
```

This mounts the same image file (which could also be a RAM disk, or any other supported block device) as DB0: on both CPA and CPB. Each `DPDISK`*c*`:` controller letter is a dual-ported drive, which must be created first. `DPDISK:` units 0 and 1 on that controller letter are the drive's two ports which can then each be mounted on a separate emulated disk controller.

F.7 DPTAPE: — Dual-ported tape

This is just like `DPDISK:`, but for tapes.

F.8 FASTBUS: — Fastbus memory on detachable Unibus segment

The PDP-11/45, PDP-11/50, and PDP-11/55 are sometimes described as having dual Unibusses. What this actually means is that any internal MS11-A/B/C semiconductor memory which is connected to the CPU's private "Fastbus" is presented as a Unibus slave for NPR purposes through a separate pair of Unibus in/out slots ("Unibus B"), while core memory (or any kind of standard Unibus memory) appears on the regular I/O bus ("Unibus A") with all of the system's other Unibus peripherals, including the three quad SPC slots in the CPU backplane itself.

Normally this is all connected together as one Unibus using an M9200 jumper in the A/B positions of slots 26 and 27 of the processor backplane, but it need not be. The internal semiconductor memory may be separated, in which case it is not available for NPRs from peripherals on Unibus A.

This separate Unibus B can be connected to a separate DMA-only bus (using an M9300 to grant NPRs in place of a processor), for use e.g. on the "Unibus B" side of an RH11 Massbus adapter. Or, the Unibus B connections can be used to make the internal memory act as a slave device to an entirely separate processor, such as Unibus A of another PDP-11/45. In this way a multi-processor system can be built where each processor makes a portion (the Fastbus part) of its memory available to another processor or processors. The memory controller is dual-ported between its PDP-11/45 host and Unibus B. The catch is that a system with split Unibusses is unable to use DMA to access its own internal memory, so presumably it will also have some Unibus memory for use with its mass storage.

A Fastbus memory is created with the following command:

`ATTACH FASTBUS`*p*`:` *start*`:`*end*

This creates a block of memory on processor `CP`*p* (which is the only processor that can't access the memory by DMA), covering the specified absolute address range. This range must be outside of regular memory, so the I/O

page will probably have to be enlarged (using the `/IOPAGE:`*nnnn* switch on the E11 startup command line so that the desired address range begins at or above the line between plain memory and I/O space.

The memory is attached to other processors by issuing the same `ATTACH` commands (with the identical address range, or with the address range omitted) while the other processor has the debugger focus (because of the `CPA`, `CPB` etc. commands). Unlike real hardware, E11 allows the same memory to be visible to more than two processors. If the very first `ATTACH` command gives one processor in the `FASTBUS`*p*`:` device name but is issued while another processor has the debugger focus, then the memory is connected to both processors and no further commands are necessary.

F.9 IPL: — Internal inter-processor link

E11 includes a virtual inter-processor link device which can connect two emulated DR11C (DRV11) or DR11W (DRV11WA) ports to each other, for very high-speed communication between processors of a multi-processor system. The typical usage is as follows:

```
assign xa0: ipla0:
set xa1: bus=b
assign xa1: ipla1:
```

In this example, XA0: is on processor CPA by default, and XA1: is explicitly put on CPB. Each `IPL`*c*`:` controller letter represents a link, and units 0 and 1 are the two endpoints of that link.

Appendix G

Dates and Times

Ersatz-11 has several features that facilitate passing date and time information back and forth between the host system and the PDP-11 operating system. The PC clock can be read or written from the PDP-11, and E11 can simulate a software bootstrap of RT-11 and RSTS/E so that these systems will pick up the current time as if they were started with a warm boot from a monitor that was already running.

G.1 Booting

RT-11 and RSTS/E both have methods for discovering whether they were software booted from another running RT-11 or RSTS/E monitor, and if so they can "inherit" the time and date from that monitor. E11's `BOOT` command can simulate this situation. If you use it with a `/RT11` or `/RSTS` switch, it obtains the current PC date and time and passes them on to the PDP-11 operating system.

E11's keyscript language has commands which allow composing a time and/or date string in almost any format, so that it may be entered with a single keystroke. The default keyscript for the F12 key sends the current time and date in a format accepted by recent versions of RSX, so it may be pressed in response to the date/time prompt at system startup. See Appendix A for information on keyscript commands, and type `SHOW KEY F12` at the E11 command prompt to see how the existing binding works.

Newer versions of DEC operating systems have support for the KDJ11E TOY clock, which E11 emulates using the host operating system's clock. For example, the RSX "`TIM /SYN`" command will read the RSX time from the PC, and "`TIM /SETTOY`" will set the PC clock from the RSX time. These commands work only if RSX has detected a KDJ11E-based CPU (i.e. PDP-11/93 or PDP-11/94), however E11 can add the TOY clock to any CPU emulation by adding `ASR` to the end of the `SET CPU` command (since the TOY clock is accessed through the Additional Status Register). A `TOY.TSK` program is available from `ftp.dbit.com` which has `/SYN` and `/SETTOY` switches which work just like the TIM command, but with no restriction on the CPU type, and it doesn't have the year 2000 problem that `TIM /SYN` did in earlier versions of RSX.

G.2 PC clock

PCs don't have a 50/60 Hz line frequency clock, so E11 simulates the KW11L style clock by reprogramming the PC's crystal-controlled interval timer for 50 or 60 Hz (the `SET HZ` command selects which frequency, the default is

60 Hz). These speeds can not be produced precisely by the PC's interval timer (it uses rather odd numbers since its master clock is the 14.31818 MHz ISA bus clock fed into a divide-by-12 counter), so E11 programs it as close as possible to the right value, and then uses fractional math to decide when to insert "leap ticks" so that the average rate will be exactly 50 or 60 Hz. In practice, this is not perfectly accurate because many (or most) PCs don't have a very accurate 14.31818 MHz clock to begin with. So their clocks tend to gain or lose time regardless of what applications software or operating system is running.

E11's solution to this is the `SET CLOCK` command, which allows adjustment of the actual master clock frequency value (which can be specified in 1 Hz increments) which E11 uses to calculate the interval clock divisor and schedule leap ticks. There's no need to actually measure the master clock frequency on the PC's motherboard, simply experimenting with values can greatly improve the accuracy and of course letting the system run for a while and then checking its clock will allow you to figure out the exact drift.

G.3 Year 2000 issues

Ersatz-11 has no year 2000 issues of its own. It does very little manipulation of dates, and when dates are handled internally it uses 16 bits to hold the year, which is enough to last until the year 65,535 AD. However problems do occur when translating dates to and from the formats required by the various PDP-11 operating systems, the PC operating system, and the KDJ11E TOY clock. Also the `YEAR2` keyscript command sends only 2-digit years, but it's there for the specific purpose of working with non-Y2K-compliant PDP-11 software. If the PDP-11 software can handle 4-digit dates, use `YEAR4` instead, which is what's used in the default keyscript for F12 anyway.

G.3.1 KDJ11E TOY clock

The Dallas Semiconductor DS1215 clock chip used in the KDJ11E battery-backed time-of-year ("TOY") clock contains only two digits for the year. Therefore it inherently suffers from the year 2000 bug, and so must any accurate emulation of it, including the one in E11, otherwise it would be incompatible with PDP-11 software designed for the real thing. However this is not as bad as it might seem. Since the TOY clock is used only to hold the *current* time, the only ambiguity that the PDP-11 software has to resolve is what century it is *now*. This is as opposed to dates held in databases, file system timestamps, etc., which can represent past and future dates and so must not be ambiguous. The latest versions of most PDP-11 operating systems have been updated to use a 100-year window when interpreting the year read from the TOY clock. For example 80–99 can be taken to mean 1980–1999, and 00–79 would mean 2000–2079. Future PDP-11 operating system releases can move this window (at this point 00–99 might as well mean 2000–2099), so this scheme can be extended indefinitely. Recent versions of RSX-11M-PLUS cleverly use the TOY clock's day-of-the-week field to figure out what century this must be, so there's no need for a 100-year window.

G.3.2 Dates in RT-11 and TSX-Plus

Older versions of RT-11 used only 5 bits to store the year, as the number of years since 1972. This format stopped working on 01-Jan-2004, and the older RT-11 versions (V5.6 and earlier) have year 2000 problems too so they had already stopped working correctly anyway. Newer versions of RT-11 adapt two previously unused bits in the date word to extend the year offset to 7 bits, which will last until 31-Dec-2099. RT-11 V5.7 is the first version that fully implements this change in all utilities as well as the monitor. TSX-Plus V6.50 also supports the 7-bit year field, so when installed on top of RT-11 V5.7 it too will last until 31-Dec-2099.

G.3.3 Dates in RSX

RSX's internal date format uses a 16-bit word to hold the number of years since 1900. This format will last for many millennia, and it's unusual in that it allows going back all the way to 1900 so that dates in the low 2000s really are ambiguous when expressed in only two digits. Current versions of RSX accept four-digit years in user commands and process them correctly, but older versions are limited to two-digit years which are all assumed to be in the 1900s. Also, the Files-11 ODS-1 disk structure used by RSX and IAS uses only 2-digit years, stored as ASCII digits rather than binary values. Newer versions of RSX extend this format for several more centuries by allowing the "10s" digit to take on the value of characters which follow "9" in the ASCII code.

G.3.4 Dates in RSTS/E

RSTS/E uses the same date format as the old DOS/BATCH system. This consists of the number of years since 1970, times 1000 (decimal), plus the day within the year (1 = January 1), stored as a 16-bit word. In older versions of RSTS/E this word was signed, so its maximum usable value was 32365., or 31-Dec-2002. Again, year 2000 problems with INIT.SYS's time/date parser prevented getting even that far. Newer versions of RSTS/E have changed to using an unsigned date word (negative values were never allowed anyhow), so now it lasts until 31-Dec-2035. Unfortunately RSTS/E's extension to the date format is not applicable to the few remaining DOS/BATCH systems, since DOS/BATCH uses the sign bit of the date word in directory entries to flag a file as contiguous, so it's not available for expansion of the date word. Multiplying the year offset by 1000 makes for very sparse usage of the available date word values, so there is room for expansion of the date format (using day-within-year values from 367 to 999) if that ever becomes necessary, but updates to PDP-11 software will be required.

G.3.5 Dates in Fuzzball

Although the Fuzzball operating system emulates the RT-11 system calls, it actually uses its own 14-bit date format internally instead of RT-11's format. This is encoded as the number of days since 01-Jan-1972, so it runs out in 2016. Fuzzball has year 2000 problems, but replacement modules are available from `ftp.dbit.com` to make it work until 2016. The date format could be extended to 16 bits, but that would require relocating the flags that currently go in the high 2 bits of the date word, and the `.GDAT` system call would require an incompatible change to support that.

G.3.6 Dates in Unix

Unix (and Unix-compatible) systems normally store dates as a signed number containing the number of seconds since midnight UTC on 01-Jan-1970. The type that this value is stored in ("`time_t`") is normally a 32-bit signed integer (in some cases this is true even on Unix systems that run on 64-bit processors), which means that this format will run out in early 2038. This limit applies both to PDP-11 Unix systems being run under emulation, as well as 80x86 Unix or Linux systems being used as the host environment for Ersatz-11.